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ESE 2019

Preliminary Examination

Detailed Solutions of
Mechanical Engineering
(Set-A)

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Expected Cutoff of ESE 2019 Prelims					Actual Cutoff of ESE 2018 Prelims				
Branch	Gen	OBC	SC	ST	Branch	Gen	OBC	SC	ST
CE	180-190	170-180	150-160	150-160	CE	207	194	169	188
ME	190-200	180-190	160-170	160-170	ME	256	255	220	223
EE	230-240	220-230	190-200	190-200	EE	230	218	190	191
E&T	210-220	200-210	170-180	170-180	E&T	213	206	173	155

Mechanical Engineering Paper Analysis ESE 2019 Prelims Exam

Sl.	Subjects	Number of Questions
1	Strength of Materials	17
2	Machine Designs	7
3	Industrial Engineering	4
4	Production	6
5	Theory of Machines	16
6	Material Science	13
7	Thermodynamics	8
8	RAC	8
9	HMT	7
10	Power Plant	17
11	IC Engine	6
12	Fluid Mechanics	15
13	Renewable Source of energy	12
14	Mechatronics	13
15	Robotics	4
16	Engineering Mechanics	2

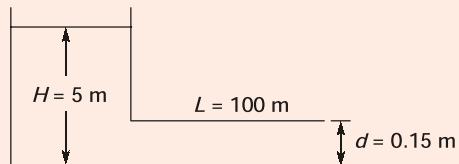
UPSC ESE/IES Prelims 2019

Mechanical Engineering analysis and expected cutoff by
MADE EASY faculty

<https://youtu.be/HEjIB35jn7s>

1. Water is discharged from a tank maintained at a constant head of 5 m above the exit of a straight pipe 100 m long and 15 cm in diameter. If the friction coefficient for the pipe is 0.01, the rate of flow will be nearly
- (a) 0.04 m³/s (b) 0.05 m³/s
(c) 0.06 m³/s (d) 0.07 m³/s

Ans. (d)



f' is friction coefficient.

$$h_f = \frac{32f'LQ^2}{\pi^2 d^5 \cdot g}$$

$$Q = \sqrt{\frac{\pi^2 d^5 g h_f}{32f'L}} = 0.035 \text{ m}^3/\text{s}$$

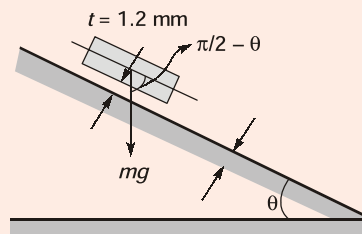
If f is friction factor $h_f = \frac{8fLQ^2}{\pi^2 d^5 \cdot g}$

$$Q = \sqrt{\frac{h_f \cdot \pi^2 d^5 \cdot g}{8fL}} = 0.068 \approx 0.07 \text{ m}^3/\text{s}$$

End of Solution

2. A plate weighing 150 N and measuring 0.8 m × 0.8 m just slides down an inclined plane over an oil film of 1.2 mm thickness for an inclination of 30° and velocity of 0.2 m/s. Then the viscosity of the oil used is:
- (a) 0.3 Ns/m² (b) 0.4 Ns/m²
(c) 0.5 Ns/m² (d) 0.7 Ns/m²

Ans. (d)



$$mg \cos\left(\frac{\pi}{2} - \theta\right) = \frac{\mu V}{t} \times A$$

$$mg \sin \theta = \frac{\mu V}{t} \times A$$

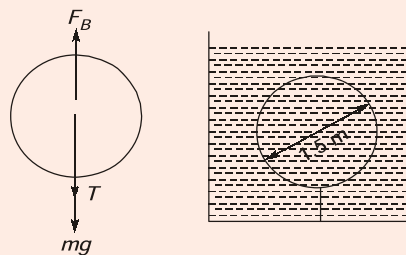
$$150 \times \sin 30 = \frac{\mu \times 0.2}{1.2 \times 10^{-3}} \times (0.8 \times 0.8)$$

$$\mu = 0.703 \frac{\text{N} \cdot \text{s}}{\text{m}^2}$$

End of Solution

3. A spherical balloon of 1.5 m diameter is completely immersed in water and chained to the bottom. If the chain has a tension of 10 kN, the weight of the balloon will be nearly
- (a) 9.11 kN (b) 8.22 kN
(c) 6.44 kN (d) 7.33 kN

Ans. (d)



$$F_B = mg + T$$

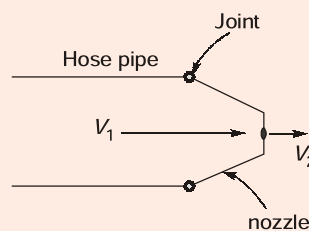
$$mg = F_B - T = \rho g V - T$$

$$mg = 1000 \times 9.81 \times \left(\frac{4}{3} \pi \times (0.75)^3 \right) - 10 \times 10^3 \text{ N} = 7.33 \text{ kN}$$

End of Solution

4. A nozzle at the end of an 80 mm hosepipe produces a jet 40 mm in diameter. When it is discharging the water 1200 Lpm, the force on the joint at the base of the nozzle will be
- (a) 180 N (b) 200 N
(c) 220 N (d) 240 N

Ans. (d)



$$F = \dot{m}V_2 - \dot{m}V_1$$

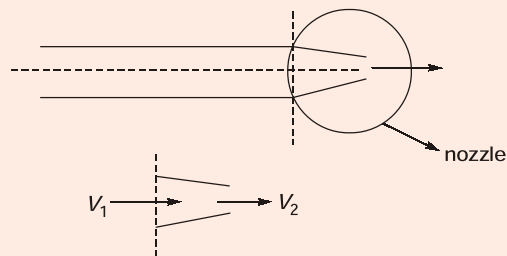
$$F = \dot{m}(V_2 - V_1) = \dot{m}V_1 \left(\frac{V_2}{V_1} - 1 \right)$$

$$F = \rho Q V_1 \left(\frac{V_2}{V_1} - 1 \right)$$

$$\begin{aligned} \therefore A_1 V_1 &= A_2 V_2 \\ \frac{V_2}{V_1} &= \frac{A_1}{A_2} = \frac{d_1^2}{d_2^2} \\ \therefore \frac{V_2}{V_1} &= \frac{0.08^2}{0.04^2} = 4 \\ Q &= A_1 V_1 \\ V_1 &= 3.97 \text{ m/s} \end{aligned}$$

$$\begin{aligned} F &= 1000 \times 0.02 \times 3.97 \left(\frac{4}{1} - 1 \right) \\ F &= 238.2 \text{ N} \approx 240 \text{ N} \end{aligned}$$

Alternate solution:



$$\begin{aligned} F_{\text{net}} &= (\dot{m}v)_{\text{out}} - (\dot{m}v)_{\text{in}} \\ F &= \dot{m}v_2 - \dot{m}v_1 \\ F &= \dot{m}(V_2 - V_1) \\ &= \dot{m} \left(\frac{V_2}{V_1} - 1 \right) = \rho Q V_1 (4 - 1) \\ &= 1000 \times 0.02 \times 3.98 \times 2 = 238.8 \text{ N} \end{aligned}$$

$$V_1 = \frac{4Q}{\pi d_1^2} = 3.98 \text{ m/s}$$

$$d_1^2 V_1 = d_2^2 V_2$$

$$\frac{d_1^2}{d_2^2} V_1 = V_2$$

$$\frac{V_2}{V_1} = \frac{d_1^2}{d_2^2}$$

$$\frac{V_2}{V_1} = 4$$

End of Solution

7. In a laminar flow through pipe, the point of maximum instability exists at a distance of y from the wall which is
- (a) $\frac{3}{2}$ of pipe radius R (b) $\frac{2}{3}$ of pipe radius R
(c) $\frac{1}{2}$ of pipe radius R (d) $\frac{1}{3}$ of pipe radius R

Ans. (b)

End of Solution

8. $Q = \frac{\partial u'}{\partial x} = -\frac{\partial v'}{\partial y}$ for a turbulent flow signifies
- (a) conservation of bulk momentum transport
(b) increase in u' in x -direction followed by increase in v' in negative y -direction
(c) turbulence is anisotropic
(d) turbulence is isotropic

Ans. (b)

End of Solution

9. A flow field satisfying $\nabla \cdot \vec{V} = 0$ as the continuity equation represents always
- (a) a steady compressible flow
(b) an incompressible flow
(c) an unsteady and incompressible flow
(d) an unsteady and compressible flow

Ans. (b)

End of Solution

10. An oil of viscosity 8 poise flows between two parallel fixed plates, which are kept at a distance of 30 mm apart. If the drop of pressure for a length of 1 m is 0.3×10^4 N/m² and width of the plates is 500 mm, the rate of oil flow between the plates will be
- (a) 4.2×10^{-3} m³/s (b) 5.4×10^{-3} m³/s
(c) 6.6×10^{-3} m³/s (d) 7.8×10^{-3} m³/s

Ans. (a)

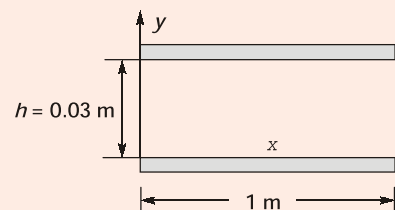
$$u = \frac{1}{2\mu} \left(\frac{-\partial P}{\partial x} \right) (hy - y^2)$$

$$\bar{u} = \frac{h^2}{12\mu} \left(\frac{-\partial P}{\partial x} \right)$$

$$\bar{u} = \frac{(0.03)^2}{12 \times 0.8} \times \left(\frac{0.3 \times 10^4}{1} \right)$$

$$\bar{u} = 0.281 \text{ m/s}$$

$$Q = \bar{u} \times (h \times b) = 4.2 \times 10^{-3} \text{ m}^3/\text{s}$$



End of Solution

11. In case of transmission of hydraulic power by a pipeline to a turbine in a hydroelectric power station, the maximum power transmission efficiency through the pipeline is
 (a) 76% (b) 67%
 (c) 54% (d) 42%

Ans. (b)

End of Solution

12. A pipe, having a length 200 m and 200 mm diameter with friction factor 0.015, is to be replaced by a 400 mm diameter pipe of friction factor 0.012 to convey the same quantity of flow. The equivalent length of the new pipe for the same head loss will be
 (a) 8300 m (b) 8240 m
 (c) 8110 m (d) 8000 m

Ans. (d)

$$L_1 = 200 \text{ m}, d_2 = 400 \text{ mm}, d_1 = 200 \text{ mm}, f_2 = 0.012, f_1 = 0.015$$

$$\frac{8f_1L_1Q^2}{\pi^2d_1^5g} = \frac{8f_2 \times L_2 \times Q^2}{\pi^2d_2^5g}$$

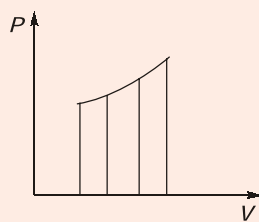
$$\frac{0.015 \times 200}{(0.2)^5} = \frac{0.012 \times L_2}{(0.4)^5}$$

$$L_2 = 8000 \text{ m}$$

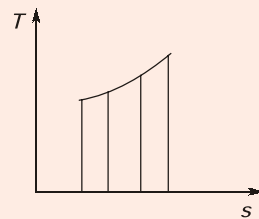
End of Solution

13. Certain quantities cannot be located on the graph by a point but are given by the area under the curve corresponding to the process. These quantities in concepts of thermodynamics are called as
 (a) cyclic functions (b) point functions
 (c) path functions (d) real functions

Ans. (c)



Area under curve on P-V represents work when projected on volume axis for closed system



Area under T-s diagram represents heat transfer for a reversible process

End of Solution

14. When 25 kg of water at 95°C is mixed with 35 kg of water at 35°C, the pressure being taken as constant at surrounding temperature of 15°C, and c_p of water is 4.2 kJ/kgK, the decrease in available energy due to mixing will be nearly
- (a) 270.5 kJ (b) 277.6 kJ
(c) 281.8 kJ (d) 288.7 kJ

Ans. (c)

$$\begin{aligned} \text{Heat lost} &= \text{Heat gained} \\ m_1 c \{95 - t\} &= m_2 c \{t - 35\} \\ 25\{95 - t\} &= 35\{t - 35\} \\ 2735 - 25t &= 35t - 1225 \\ 3600 &= 60t \\ t &= 60^\circ\text{C} \\ T &= 333\text{ K} \\ S_{\text{gen}} &= \Delta S_1 + \Delta S_2 \\ &= m_1 c \ln \frac{T}{T_1} + m_2 c \ln \frac{T}{T_2} \\ &= 25 \times 4.2 \ln \frac{333}{273 + 95} + 35 \times 4.2 \ln \frac{333}{273 + 35} \\ &= -10.4938 + 11.472 = 0.9784 \\ \text{Loss of A.E.} &= \text{Irreversibility} = T_0 \cdot S_{\text{gen}} \\ &= 288 \times 0.9784 = 281.80\text{ kJ} \end{aligned}$$

End of Solution

15. A frictionless piston cylinder device contains 5 kg of steam at 400 kPa and 200°C. The heat is now transferred to the steam until the temperature reaches 250°C. If the piston is not attached to a shaft, its mass is constant, and by taking the values of specific volume v_1 as 0.53434 m³/kg and v_2 as 0.59520 m³/kg, the work done by the steam during this process is
- (a) 121.7 kJ (b) 137.5 kJ
(c) 153.3 kJ (d) 189.1 kJ

Ans. (a)

Constant pressure process

$$\begin{aligned} \text{Work} &= P(V_2 - V_1) \\ &= P \times m(v_2 - v_1) = 400 \times 5(0.59520 - 0.53434)\text{ kJ} \\ &= 121.72\text{ kJ} \end{aligned}$$

End of Solution

16. A diesel engine has a compression ratio of 14 and cutoff takes place at 6% of the stroke. The air standard efficiency will be
 (a) 74.5 % (b) 60.5%
 (c) 52.5% (d) 44.5%

Ans. (b)

$$\begin{aligned} r &= 14, \quad \%p = 6\%, \quad \gamma = 1.4 \\ \Rightarrow \quad \rho &= \%p(r - 1) + 1 = 1.78 \\ \eta_d &= 1 - \left(\frac{1}{r}\right)^{\gamma-1} \times \frac{(\rho^\gamma - 1)}{\gamma(r-1)} = 60.4\% \end{aligned}$$

End of Solution

17. A gas mixture consists of 3 kg of O₂, 5 kg of N₂ and 12 kg of CH₄. The mass fraction and mole fraction of O₂ are
 (a) 0.25 and 0.125 (b) 0.15 and 0.092
 (c) 0.25 and 0.092 (d) 0.15 and 0.125

Ans. (b)

$$\text{Mass fraction of O}_2 = \frac{3}{3+5+12} = 0.15$$

$$\text{Mole fraction of O}_2 = \frac{n_{\text{O}_2}}{n_{\text{O}_2} + n_{\text{N}_2} + n_{\text{CH}_4}} = \frac{\frac{3}{32}}{\frac{3}{32} + \frac{5}{28} + \frac{12}{16}} = 0.0917 \approx 0.092$$

Alternate solution:

$$m_{\text{O}_2} = 3 \text{ kg}, \quad m_{\text{N}_2} = 5 \text{ kg}, \quad m_{\text{CH}_4} = 12 \text{ kg}$$

$$\text{Mass fraction of O}_2 = \frac{m_{\text{O}_2}}{m_{\text{O}_2} + m_{\text{N}_2} + m_{\text{CH}_4}} = \frac{3}{3+5+12} = \frac{3}{20} = 0.15$$

$$n_{\text{O}_2} = \frac{3}{32} = 0.09375$$

$$n_{\text{N}_2} = \frac{5}{28} = 0.17857$$

$$n_{\text{CH}_4} = \frac{12}{16} = 0.75$$

$$\text{Mole fraction of O}_2 = \frac{n_{\text{O}_2}}{n_{\text{O}_2} + n_{\text{N}_2} + n_{\text{CH}_4}} = 0.0917$$

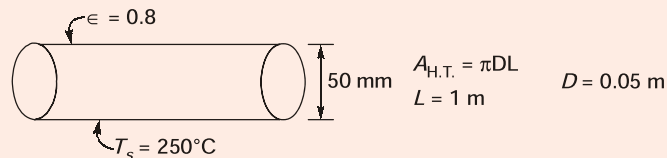
End of Solution

18. An insulated pipe of 50 mm outside diameter with $\epsilon = 0.8$ is laid in a room at 30°C . If the surface temperature is 250°C and the convective heat transfer coefficient is $10\text{ W/m}^2\text{K}$, the total heat loss per unit length of the pipe will be:

- (a) 896.6 W/m (b) 818.8 W/m
(c) 786.4 W/m (d) 742.2 W/m

Ans. (b)

$$h = 10\text{ W/m}^2\text{K} \quad T_\infty = 30^\circ\text{C}$$



Total H.T. rate per unit length = H.T. rate by convection to air per unit length
+ H.T. rate by radiation to ambient per unit length

$$\begin{aligned} &= \frac{hA(T_s - T_\infty)}{L} + \frac{\sigma \epsilon A}{L}(T_s^4 - T_\infty^4) \\ &= \frac{h\pi DL(T_s - T_\infty)}{L} + \frac{\sigma \epsilon (\pi DL)(T_s^4 - T_\infty^4)}{L} \\ &= 10 \times \pi \times 0.5 (250 - 30) \\ &\quad + 5.67 \times 10^{-8} \times 0.8 \times \pi \times 0.05 \times (523^4 - 303^4) = 818.8\text{ W/m} \end{aligned}$$

End of Solution

19. A wire of 8 mm diameter at a temperature of 60°C is to be insulated by a material having $k = 0.174\text{ W/m K}$. The heat transfer coefficient on the outside $h_a = 8\text{ W/m}^2\text{K}$ and ambient temperature $T_a = 25^\circ\text{C}$. The maximum thickness of insulation for maximum heat loss will be:

- (a) 15.25 mm (b) 16.50 mm
(c) 17.75 mm (d) 18.25 mm

Ans. (c)

Critical radius of insulation

$$= r_{\text{critical}} = \frac{k_{\text{ins}}}{h} = \left(\frac{0.174}{8} \right) \text{ m} = 0.02175\text{ m}$$

\therefore Critical thickness of insulation

$$= r_{\text{critical}} - r_{\text{wire}} = (0.02175 - 0.004)\text{ m} = 17.75\text{ mm}$$

End of Solution

20. In liquid metals, thermal boundary layer develops much faster than velocity boundary layer due to
- (a) lower value of Nusselt number (b) higher value of Prandtl number
(c) lower value of Prandtl number (d) higher value fo Nusselt number

Ans. (c)

For liquid metals (like mercury), Prandtl number is very low since they have high thermal conductivity.

By definition $P_r = \frac{\nu}{\alpha}$ i.e. $\delta \ll \delta_t$
 $\delta = \text{H.B.L. thickness}; \delta_t = \text{T.B.L. thickness}$

End of Solution

21. The temperature of a body of area 0.1 m^2 is 900 K . The wavelength for maximum monochromatic emissive power will be nearly
- (a) $2.3 \mu\text{m}$ (b) $3.2 \mu\text{m}$
(c) $4.1 \mu\text{m}$ (d) $5.0 \mu\text{m}$

Ans. (b)

According to Wein's Displacement Law,

$$\lambda_m T = \text{constant} = 2898 \mu\text{m-K}$$

$$\therefore \lambda_m \times 900 = 2898 \mu\text{m-K}$$

$$\Rightarrow \lambda_m = \frac{2898}{900} = 3.22 \mu\text{m}$$

where, $\lambda_m = \text{wavelength at which } E_{b\lambda} \text{ is maximum}$

End of Solution

22. Consider the following statements:
 For the laminar condensation on a vertical plate, the Nusselt theory says that
1. inertia force in the film is negligible compared to viscosity and weight.
 2. heat flow is mainly by conduction through the liquid film, convection in liquid film as well as in vapour is neglected.
 3. velocity of vapour is very high.
- Which of the above statements are correct?
- (a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

Ans. (b)

Momentum and energy transfers by advection in the condensate film are assumed to be negligible.

End of Solution

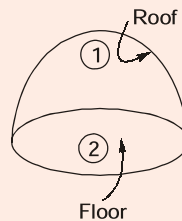
23. In transition boiling, heat flux decreases due to which of the following?
1. Low value of film heat transfer coefficient at the surface during 100 °C to 120 °C surface temperature.
 2. Major portion of heater surface is covered by vapour film which has smaller thermal conductivity as compared to liquid
 3. Nucleate boiling occurs very fast.
- Select the correct answer using the code given below
- (a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

Ans. (b)

End of Solution

24. A hemispherical furnace of radius 1.0 m has a roof temperature of $T_1 = 800$ K and emissivity $\epsilon_1 = 0.8$. The flat floor of the furnace has a temperature $T_2 = 600$ K and emissivity $\epsilon_2 = 0.5$. The view factor F_{12} from surface 1 to 2 will be:
- (a) 0.3 (b) 0.4
(c) 0.5 (d) 0.6

Ans. (c)



$$F_{21} = 1$$

$$A_1 F_{12} = A_2 F_{21}$$

$$F_{12} = \frac{A_2}{A_1} \times 1 = \frac{\pi R^2}{2\pi R^2} = \frac{1}{2}$$

End of Solution

25. Consider the following statements :
- Combustion chamber is
1. the volume between TDC and BDC during the combustion process
 2. the space enclosed between the upper part of the cylinder and the top of the piston during the combustion process
 3. the space enclosed between TDC and the top of the piston during the combustion process
- Which of the above statements is /are correct?
- (a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

Ans. (b)

End of Solution

26. A 4-stroke diesel engine has length of 20 cm and diameter of 16 cm. The engine is producing power of 25 kW when it is running at 2500 r.p.m. The mean effective pressure of the engine will be nearly
- (a) 5.32 bar (b) 4.54 bar
(c) 3.76 bar (d) 2.98 bar

Ans. (d)

$L = 20 \text{ cm}$, $D = 16 \text{ cm}$, B.P. = 25 kW, $N = 2500 \text{ rpm}$

$$P_m = \frac{B.P.}{V_s} = \frac{B.P.}{\frac{\pi}{4} \times D^2 \times L \times k \times \frac{N}{60 \times 2}} = 2.98 \text{ bar}$$

End of Solution

27. A 4-stroke, 6-cylinder gas engine with a stroke volume of 1.75 litres develops 26.25 kW at 500 r.p.m. and the *MEP* is 600 kN/m². The number of misfires per minute per cylinder will be
- (a) 3 (b) 4
(c) 5 (d) 6

Ans. (a)

B.P. = 26.25, $N = 500 \text{ rpm}$, $P_{bm} = 600 \text{ kN/m}^2$, $V_s = 1.75 \text{ litre}$

If, $N = 500 \text{ rpm}$ then B.P. = 26.25 kW

∴ It is 4-stroke gas engine, so $N_{\text{eff}} = N/2$

So, '3' misfiring occurs per minute per cylinder

End of Solution

28. Which one of the following compressors will be used in vapour compression refrigerator for plants up to 100 tonnes capacity?
- (a) Reciprocating compressor (b) Rotary compressor
(c) Centrifugal compressor (d) Double-acting compressor

Ans. (c)

End of Solution

29. A cold storage is to be maintained at -5°C while the surroundings are at 35°C . The heat leakage from the surroundings into the cold storage is estimated to be 29 kW. The actual

COP of the refrigeration plant used is $\frac{1}{3}$ rd that of an ideal plant working between the

same temperatures. The power required to drive the plant will be:

- (a) 13 kW (b) 14 kW
(c) 15 kW (d) 16 kW

Ans. (a)

$$T_L = -5^\circ\text{C} = 268 \text{ K}, T_H = 35^\circ\text{C} = 308 \text{ K}$$

$$\text{COP}_{\text{actual}} = \frac{1}{3}(\text{COP})_{\text{ideal}}$$

$$= \frac{1}{3} \left\{ \frac{T_L}{T_H - T_L} \right\} = \frac{1}{3} \left\{ \frac{268}{308 - 268} \right\} = 2.233$$

$$\text{Also, } \text{COP}_{\text{actual}} = \frac{R.C.}{\dot{W}_{\text{input}}} = \frac{29}{\dot{W}_{\text{input}}}$$

$$\dot{W}_{\text{input}} = 12.987 \approx 13 \text{ kW}$$

End of Solution

30. Consider the following statements :

An expansion device in a refrigeration system

1. reduces the pressure from the condenser to the evaporator
2. regulates the flow of the refrigerant to the evaporator depending on the load
3. is essentially a restriction offering resistance to flow

Which of the above statements are correct?

- | | |
|------------------|------------------|
| (a) 1 and 2 only | (b) 1 and 3 only |
| (c) 2 and 3 only | (d) 1, 2 and 3 |

Ans. (d)

End of Solution

31. A reversed Carnot engine is used for heating a building. It supplies 210×10^3 kJ/hr of heat to the building at 20°C . The outside air is at -5°C . The heat taken from the outside will be nearly

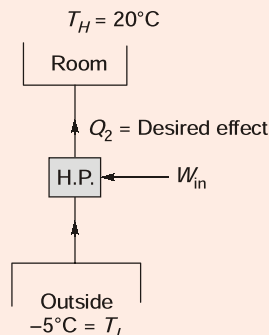
- | | |
|-----------------------------|-----------------------------|
| (a) 192×10^3 kJ/hr | (b) 188×10^3 kJ/hr |
| (c) 184×10^3 kJ/hr | (d) 180×10^3 kJ/hr |

Ans. (a)

A heat supplied to room = 210×10^3 kJ/Hr

$T_H = 20^\circ\text{C} = 293 \text{ K}$, $T_L = -5^\circ\text{C} = 268 \text{ K}$

Heat taken from outside = $\dot{Q}_1 = ?$



$$(\text{COP})_{\text{HP}} = \frac{T_H}{T_H - T_L} = \frac{\dot{Q}_2}{W_{\text{in}}} = \frac{\dot{Q}_2}{\dot{Q}_2 - \dot{Q}_1}$$

$$= \frac{293}{293 - 268} = \frac{210 \times 10^3}{210 \times 10^3 - \dot{Q}_1}$$

$$\dot{Q}_1 = 192 \times 10^3 \text{ kJ/Hr}$$

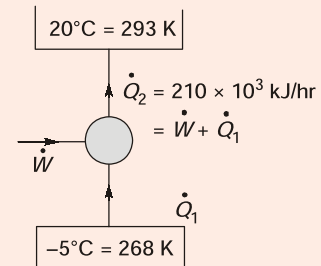
Alternate solution:

$$\oint_{rev} \frac{\delta Q}{T} = 0$$

$$\frac{\dot{Q}_1}{T_1} + \frac{\dot{Q}_2}{T_2} = 0$$

$$\frac{\dot{Q}_1}{268} + \frac{(-210 \times 10^3)}{293} = 0$$

$$\dot{Q}_1 = 192.081 \times 10^3 \text{ kJ/hr}$$



End of Solution

32. In an Electrolux refrigerator, a thermo-siphon bubble pump is used to lift the
- weak aqua solution from the generator to the separator
 - weak aqua solution from the separator to the absorber
 - strong aqua solution from the generator to the separator
 - strong aqua solution from the generator to the evaporator

Ans. (a)

End of Solution

33. The enthalpy of moist air with normal notations is given by
- $h = (1.005 + 1.88 W) t + 2500 W$
 - $h = 1.88 Wt + 2500 W$
 - $h = 1.005 W t$
 - $h = (1.88 + 1.005 W) t + 2500 W$

Ans. (a)

End of Solution

34. If the relative humidity of atmospheric air is 100%, then the wet-bulb temperature will be
- more than dry-bulb temperature
 - equal to dew-point temperature
 - equal to dry-bulb temperature
 - less than dry-bulb temperature

Ans. (b) and (c) both

End of Solution

35. During an air-conditioning of a plant, the room sensible heat load is 40 kW and room latent heat load is 10 kW, ventilation air is 25% of supply air. At full load, the room sensible heat factor will be
- 0.9
 - 0.8
 - 0.7
 - 0.6

Ans. (b)

$$\begin{aligned} \text{RSH} &= 40 \text{ kW} & \text{Total heat (TH)} &= \text{RSH} + \text{RLH} = 50 \text{ kW} \\ \text{RLH} &= 10 \text{ kW} \end{aligned}$$

$$\text{RSHF} = \frac{\text{RSH}}{\text{TH}} = \frac{40}{50} = 0.8$$

End of Solution

36. A 2-stroke oil engine has bore of 20 cm, stroke 30 cm, speed 350 r.p.m., i.m.e.p. 275 kN/m², net brake load 610 N, diameter of brake drum 1 m, oil consumption 4.25 kg/hr, calorific value of fuel 44 × 10³ kJ/kg. The indicated thermal efficiency will be
- (a) 29.1% (b) 31.3%
(c) 33.5% (d) 35.7%

Ans. (a)

2-stroke, $D = 20 \text{ cm}$, $L = 30 \text{ cm}$, $N = 350 \text{ rpm}$, $P_{im} = 275 \text{ kN/m}^2$

$$IP = P_{im} \times \dot{V}_s = 275 \times \left(\frac{\pi}{4} \times D^2 \times L \times k \times \frac{N}{60} \right)$$

$$\eta_{ith} = \frac{IP}{\dot{m}_f \times (\text{C.V.})_f} = 29.1\%$$

End of Solution

37. The hydraulic efficiency of a turbine is the ratio of
- (a) mechanical energy in the output shaft at coupling and hydrodynamic energy available from the fluid
(b) mechanical energy supplied by the rotor and hydrodynamic energy available from the fluid
(c) useful hydrodynamic energy in the fluid at final discharge and mechanical energy supplied to the rotor
(d) useful hydrodynamic energy in the fluid at final discharge and mechanical energy supplied to the shaft and coupling

Ans. (b)

$$\eta_H = \frac{\text{Runner Power}}{\text{Water Power}}$$

End of Solution

41. In axial flow pumps and compressors, the combined velocity diagram with common base is used to determine change in
- (a) absolute velocity ($V_2 - V_1$)
 - (b) relative velocity ($V_{r2} - V_{r1}$)
 - (c) tangential velocity ($U_2 - U_1$)
 - (d) whirl velocity ($V_{u2} - V_{u1}$)

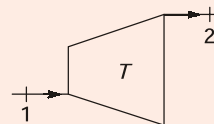
Ans. (d)

End of Solution

42. In a steam turbine with steam flow rate of 1 kg/s, inlet velocity of steam of 100 m/s, exit velocity of steam of 150 m/s, enthalpy at inlet of 2900 kJ/kg, enthalpy at outlet of 1600 kJ/kg, the power available from the turbine will be nearly
- (a) 1575.5 kW
 - (b) 1481.6 kW
 - (c) 1387.7 kW
 - (d) 1293.8 kW

Ans. (d) (1293.75 kW)

$$\dot{m} = 1 \text{ kg/s}$$



$$\dot{m} \left\{ h_1 + \frac{C_1^2}{2000} \right\} = \dot{m} \left\{ h_2 + \frac{C_2^2}{2000} \right\} + \dot{W}_{\text{output}}$$

$$1 \left\{ 2900 + \frac{100^2}{2000} \right\} = 1 \left\{ 1600 + \frac{150^2}{2000} \right\} + \dot{W}_{\text{output}}$$

$$2905 = 1600 + 11.25 + \dot{W}_{\text{output}}$$

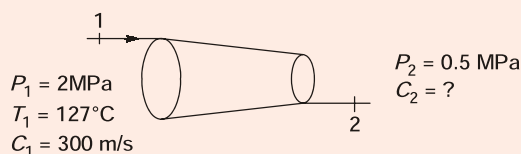
$$\dot{W}_{\text{output}} = 1293.8 \text{ kW}$$

End of Solution

43. In an isentropic flow through a nozzle, air flows at the rate of 600 kg/hr. At inlet to nozzle, the pressure is 2 MPa and the temperature is 127 °C. The exit pressure is of 0.5 MPa. If the initial velocity of air is 300 m/s, the exit velocity will be
- (a) 867 m/s
 - (b) 776 m/s
 - (c) 685 m/s
 - (d) 594 m/s

Ans. (d)

$$\dot{m} = 600 \text{ kg/hr,} = 0.167 \text{ kg/sec}$$



$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{T_2}{273+127} = \left(\frac{0.5}{2}\right)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 269.18 \text{ K}$$

$$\text{S.F.E.E. } \dot{m}\left(h_1 + \frac{C_1^2}{2000}\right) = \dot{m}\left(h_2 + \frac{C_2^2}{2000}\right)$$

$$C_p T_1 + \frac{300^2}{2000} = C_p T_2 + \frac{C_2^2}{2000}$$

$$1.005 \times 400 + 45 = 1.005 \times 269.18 + \frac{C_2^2}{2000}$$

$$C_2 = 594.094 \text{ m/s}$$

End of Solution

44. In a steam turbine, the nozzle angle at the inlet is 18° . The relative velocity is reduced to the extent of 6% when steam flows over the moving blades. The output of the turbine is 120 kJ/kg flow of steam. If the blades are equiangular, the speed ratio and the absolute velocity of steam at inlet for maximum utilization are nearly
- (a) 0.42 and 230.2 m/s (b) 0.48 and 230.2 m/s
(c) 0.42 and 515.1 m/s (d) 0.48 and 515.1 m/s

Ans. (d)

$$\rho_{\text{opt}} = \frac{v}{V_1} = \frac{\cos \alpha}{2} = \frac{\cos 18^\circ}{2} = 0.48$$

$$W = 120 \text{ kJ/kg} = u \cdot (V_{w1} + V_{w2}) = u \cdot (V_1 \cos \alpha + V_{r2} \cos \phi - u)$$

On solving $V_1 = 515.1 \text{ m/s}$

End of Solution

45. An air compressor compresses atmospheric air at 0.1 MPa and 27°C by 10 times of air inlet pressure. During compression, the heat lost to the surrounding is estimated to be 5% of compression work. Air enters the compressor with a velocity of 40 m/s and leaves with 100 m/s. The inlet and exit cross-sectional areas are 100 cm^2 and 20 cm^2 respectively. The temperature of air at the exit from the compressor will be
- (a) 1498 K (b) 1574 K
(c) 1654 K (d) 1726 K

Ans. (a)

$$P_1 = 0.1 \text{ MPa}, T_1 = 300 \text{ K}, P_2 = 1 \text{ MPa}, T_2 = ?$$

$$A_1 = 100 \text{ cm}^2, A_2 = 20 \text{ cm}^2, V_1 = 40 \text{ m/s}, V_2 = 100 \text{ m/s}$$

By continuity equation

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$\frac{P_1}{RT_1} \cdot A_1 \cdot V_1 = \frac{P_2}{RT_2} \cdot A_2 \cdot V_2$$

$$\frac{0.1 \times 100 \times 40}{300} = \frac{1 \times 20 \times 100}{T_2}$$

$$T_2 = 1500 \text{ K}$$

End of Solution

46. A compressor delivers 4 m³ of air having a mass of 5 kg. The specific weight and specific volume of air being delivered will be nearly

- (a) 12.3 N/m³ and 0.8 m³/kg (b) 14.6 N/m³ and 0.4 m³/kg
(c) 12.3 N/m³ and 0.4 m³/kg (d) 14.6 N/m³ and 0.8 m³/kg

Ans. (a)

(i) $\rho \cdot g = \frac{m}{V} \cdot g = \frac{5}{4} \times 9.81 = 12.26 \approx 12.3 \text{ N/m}^3$

(ii) $\frac{v}{m} = \frac{4}{5} = 0.8 \text{ m}^3/\text{kg}$

End of Solution

47. In centrifugal compressors, there exists a loss of energy due to the mismatch of direction of relative velocity of fluid at inlet with inlet blade angle. This loss is known as

- (a) frictional loss (b) incidence loss
(c) clearance loss (d) leakage loss

Ans. (b)

End of Solution

48. A centrifugal compressor develops a pressure ratio of 5 and air consumption of 30 kg/s. The inlet temperature and pressure are 15 °C and 1 bar respectively. For an isentropic efficiency of 0.85, the power required by the compressor will be nearly

- (a) 5964 kW (b) 5778 kW
(c) 5586 kW (d) 5397 kW

Ans. (a)

$$\frac{T_{2s}}{T_1} = \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} = 5^{1.4} = 1.583$$

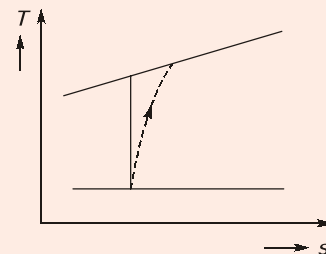
$$T_{2s} = 288 \times 1.583 = 456.1 \text{ K}$$

$$\frac{T_{2s} - T_1}{T_2 - T_1} = \eta_c = 0.85$$

$$T_2 - T_1 = 197.81 \text{ K}$$

$$W = mc_p \Delta T = 30 \times 1.005 \times 197.81$$

$$W = 5964 \text{ kW}$$



End of Solution

49. The efficiency of superheat Rankine cycle is higher than that of simple Rankine cycle because
- (a) the enthalpy of main steam is higher for superheat cycle
 - (b) the mean temperature of heat addition is higher for superheat cycle
 - (c) the temperature of steam in the condenser is high
 - (d) the quality of steam in the condenser is low

Ans. (b)

End of Solution

50. In steam power cycle, the process of removing non-condensable gases is called
- (a) scavenging process
 - (b) deaeration process
 - (c) exhaust process
 - (d) condensation process

Ans. (b)

End of Solution

51. The internal irreversibility of Rankine cycle is caused by
1. fluid friction
 2. throttling
 3. mixing

Select the correct answer using the code given below:

- (a) 1 and 2 only
- (b) 1 and 3 only
- (c) 2 and 3 only
- (d) 1, 2 and 3

Ans. (d)

End of Solution

52. A 1 g sample of fuel is burned in a bomb calorimeter containing 1.2 kg of water at an initial temperature of 25°C. After the reaction, the final temperature of the water is 33.2°C. The heat capacity of the calorimeter is 837 J/°C. The specific heat of water is 4.18 J/°C. The heat released by the fuel will be nearly
- (a) 36 kJ/g
 - (b) 42 kJ/g
 - (c) 48 kJ/g
 - (d) 54 kJ/g

Ans. (c)

$$\begin{aligned} m_f (\text{C.V.}) &= m_w c_p \Delta T + W_{\text{eq}} \times \Delta T \\ &= 1.2 \times 4.18 \times 10^3 \times 8.2 + 837 \times 8.2 \\ &= 41131.2 + 6863.4 \\ &= 47994.6 \text{ J} \approx 48000 \text{ J} \\ (\text{C.V.}) &= 48 \text{ kJ/g} \end{aligned}$$

End of Solution

53. A boiler is having a chimney of 35 m height. The draught produced in terms of water column is 20 mm. The temperature of flue gas inside the chimney is 365°C and that of air outside the chimney is 32°C. The mass of air used will be nearly
- (a) 10.3 kg/kg of fuel (b) 12.5 kg/kg of fuel
(c) 14.7 kg/kg of fuel (d) 16.9 kg/kg of fuel

Ans. (d)

$$0.02 = \frac{353 \times 35}{1000} \left\{ \frac{1}{305} - \frac{m+1}{m} \left(\frac{1}{638} \right) \right\}$$

$$\frac{20}{353 \times 35} = \left\{ \frac{1}{305} - \frac{m+1}{m} \left(\frac{1}{638} \right) \right\}$$

$$\frac{1}{617.75} = \frac{1}{305} - \frac{m+1}{m} \left(\frac{1}{638} \right)$$

$$\frac{m+1}{m} \left(\frac{1}{638} \right) = \frac{1}{305} - \frac{1}{617.75}$$

$$\frac{m+1}{m} = \frac{312.75 \times 638}{305 \times 617.75} = 1.0590$$

$$\frac{1}{m} = 0.059 \Rightarrow m = 16.9 \text{ kg/kg of fuel}$$

End of Solution

54. A 2 kg of steam occupying 0.3 m³ at 15 bar is expanded according to the law $PV^{1.3} = \text{constant}$ to a pressure of 1.5 bar. The work done during the expansion will be
- (a) 602.9 kJ (b) 606.7 kJ
(c) 612.45 kJ (d) 618.3 kJ

Ans. (d)

$$m = 2 \text{ kg}$$

$$V_1 = 0.3 \text{ m}^3$$

$$P_1 = 15 \text{ bar}$$

$$P_2 = 1.5 \text{ bar}$$

$$P_1 V_1^{1.3} = P_2 V_2^{1.3}$$

$$V_2 = \left(\frac{P_1}{P_2} \right)^{1/1.3} \times V_1$$

$$V_2 = 5.878 \times 0.3$$

$$V_2 = 1.7634 \text{ m}^3$$

$$W = \frac{P_1 V_1 - P_2 V_2}{n-1}$$

$$W = \frac{15 \times 100 \times 0.3 - 1.5 \times 100 \times 1.7634}{1.3-1} = 618.3 \text{ kJ}$$

End of Solution

- 55.** Which of the following statements is/are correct regarding superheater in boilers?
1. It is a heat exchanger in which heat is transformed to the saturated steam to increase its temperature.
 2. It raises the overall efficiency.
 3. It reduces turbine internal efficiency.
- Select the correct answer using the code given below:

- (a) 1 and 2
(b) 1 and 3
(c) 2 and 3
(d) 1 only

Ans. (a)

End of Solution

- 56.** Water vapour at 90 kPa and 150°C enters a subsonic diffuser with a velocity of 150 m/s and leaves the diffuser at 190 kPa with a velocity of 55 m/s, and during the process, 1.5 kJ/kg of heat is lost to the surrounding. For water vapour, c_p is 2.1 kJ/kgK. The final temperature of water vapour will be
- (a) 154°C (b) 158°C
(c) 162°C (d) 166°C

Ans. (a)

$$\begin{aligned} P_1 &= 90 \text{ kPa}, P_2 = 190 \text{ kPa} \\ T_1 &= 150^\circ\text{C} \\ C_1 &= 150 \text{ m/s}, C_2 = 55 \text{ m/s} \end{aligned}$$

S.F.E.E.

$$h_1 + \frac{C_1^2}{2000} + q = h_2 + \frac{C_2^2}{2000}$$

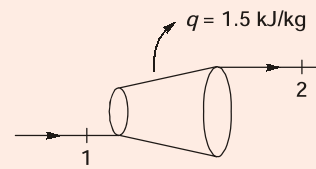
$$c_p T_1 + \frac{150^2}{2000} + (-1.5) = c_p T_2 + \frac{55^2}{2000}$$

$$2.1 \times 423 + \frac{150^2}{2000} - 1.5 = 2.1 \times T_2 + \frac{55^2}{2000}$$

$$888.3 + 11.25 - 1.5 = 2.1 \times T_2 + 1.5125$$

$$T_2 = 426.922 \text{ K}$$

$$T_2 = 153.922^\circ\text{C}$$



End of Solution

- 57.** A steam turbine is supplied with steam at a pressure of 20 bar gauge. After expansion in the steam turbine, the steam passes to condenser which is maintained at a vacuum of 250 mm of mercury by means of pumps. The inlet and exhaust steam pressures will be nearly
- (a) 2101 kPa and 68 kPa (b) 2430 kPa and 78 kPa
(c) 2101 kPa and 78 kPa (d) 2430 kPa and 68 kPa

Ans. (a)

$$P_1 = 20 + 1.01325$$

$$= 21.01325 \text{ bar} = 2101 \text{ kPa}$$

$$250 \text{ mm hg.} = \frac{250}{760} \times 101.325 = 33.33 \text{ kPa}$$

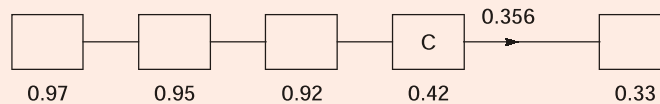
$$P_2 = 101.325 - 33.33 = 67.995 \approx 68 \text{ kPa}$$

End of Solution

58. In a power plant, the efficiencies of the electric generator, turbine, boiler, thermodynamic cycle and the overall plant are 0.97, 0.95, 0.92, 0.42 and 0.33 respectively. The total electricity generated for running the auxiliaries will be nearly

- (a) 4.9% (b) 5.7%
(c) 6.5% (d) 7.3%

Ans. (d)



$$\Delta_{\text{Aux}} = \frac{0.356 - 0.33}{0.356} = 0.0730 = 7.3\%$$

End of Solution

59. A turbine in which steam expands both in nozzle as well as in blades is called as
(a) impulse reaction turbine (b) reciprocating steam turbine
(c) gas turbine (d) Curtis turbine

Ans. (a)

End of Solution

60. Consider the following statements regarding reaction turbine:
1. Blade shape is aerofoil type and its manufacturing is difficult.
2. It is suitable for small power.
3. Leakage losses are less compared to friction losses.
Which of the above statements is/are correct?

- (a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

Ans. (a)

End of Solution

61. The solar heat pipe works on the principle of
- (a) heating and condensation cycle
 - (b) evaporation and condensation cycle
 - (c) cooling and condensation cycle
 - (d) heating and evaporation cycle

Ans. (b)

End of Solution

62. A good approximation of the measured solar spectrum is made by
- (a) black-body energy distribution
 - (b) Planck's energy distribution
 - (c) inverse square law
 - (d) solar constant

Ans. (b)

End of Solution

63. Which one of the following types of tracker uses liquid contained in canisters that can turn easily into vapour?
- (a) Active tracker
 - (b) Passive tracker
 - (c) Single-axis tracker
 - (d) Altitude-azimuth tracker

Ans. (b)

End of Solution

64. Which type of flat-plate collector is used to heat the swimming pools with plastic panel, utilizing solar energy?
- (a) Pipe and fin type
 - (b) Full water sandwich type
 - (c) Thermal traps type
 - (d) Corrugated plate with selective surface type

Ans. (b)

End of Solution

65. The edge loss U_e in a solar collector with respect to edge area A_e , collector area A_c and back loss coefficient U_b is

- (a) $U_b \left(\frac{A_e}{A_c} \right)$
- (b) $U_b \left(\frac{A_c}{A_e} \right)$
- (c) $A_c \left(\frac{A_e}{U_b} \right)$
- (d) $U_b \left(\frac{A_e}{2A_c} \right)$

Ans. (a)

End of Solution

66. In solar porous type air heater, the pressure drop is usually
 (a) higher than non-porous type (b) same as in non-porous type
 (c) lower than non-porous type (d) zero

Ans. (c)

End of Solution

67. In a drainback solar water heating system
 (a) the water in the heat exchange is recycled
 (b) the water is heated in collectors only during times when there is available heat
 (c) at the collector, the mixture of water and propylene-glycol is heated and returned to a solar storage tank
 (d) there is an expansion tank with enclosed air chamber to assist water draining

Ans. (*)

End of Solution

68. A PV cell is illuminated with irradiance (E) of 1000 W/m^2 . If the cell is $100 \text{ mm} \times 100 \text{ mm}$ in size and produces 3 A at 0.5 V at the maximum power point, the conversion efficiency will be
 (a) 15% (b) 19%
 (c) 23% (d) 27%

Ans. (a)

$$\eta_{\text{conv}} = \frac{P_{\text{max}}}{G_s \times A_c}$$

$G_s \rightarrow$ Total solar radiation incident flux

$$\eta_{\text{conv}} = \frac{P_{\text{max}}}{G_s \times A_c} = \frac{0.5 \times 3}{1000 \times 0.1 \times 0.1} = 0.15 = 15\%$$

End of Solution

69. In a barrage of 300000 m^2 area with a tide height of 3 m , barrage drain time of 10 hr , density of seawater as 1025 kg/m^3 and gravitational acceleration as 9.8 m/s^2 , the average power will be
 (a) 377 kW (b) 381 kW
 (c) 388 kW (d) 396 kW

Ans. (a)

$$P_{\text{avg}} = \frac{1}{2} \frac{\rho A g R^2}{10 \times 3600}$$

$$= \frac{1}{2} \frac{1025 \times 300000 \times 9.8 \times 3^2}{10 \times 3600} = 376.68 \text{ kW}$$

End of Solution

70. The platinum nano-coating is made on the anode of the fuel cell to
- (a) create lighter and more efficient fuel cell membranes
 - (b) make the fuel effective
 - (c) create high thermal conductivity in the cell
 - (d) make the fuel cell non-corrosive

Ans. (a)

End of Solution

71. In a fuel cell, electric current is produced when
- (a) hydrogen and oxygen react with each other and electrons are freed
 - (b) hydrogen reacts with water and electrons are freed
 - (c) oxygen reacts with water and electrons are freed
 - (d) electrons react with molecules of hydrogen and oxygen is freed

Ans. (a)

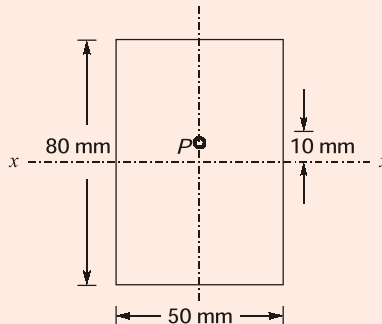
End of Solution

72. Which one of the following is suitable for fuel cell electric vehicle (FCEV)?
- (a) Direct methanol fuel cell (DMFC)
 - (b) Alkaline fuel cell (AFC)
 - (c) Proton exchange membrane fuel cell (PEMFC)
 - (d) Solid oxide fuel cell (SOFC)

Ans. (c)

End of Solution

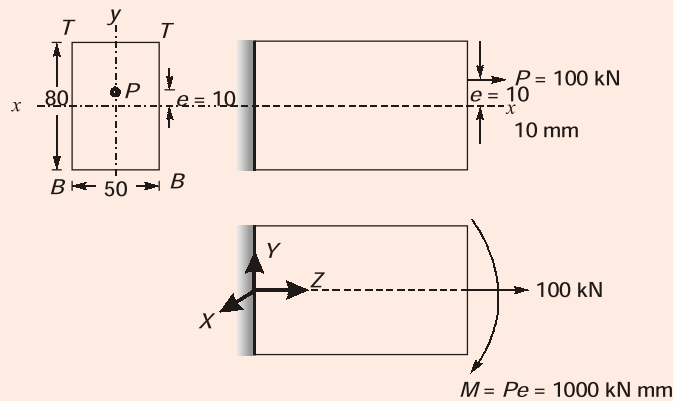
73. A pull of 100 kN acts on a bar as shown in the figure in such a way that it is parallel to the bar axis and is 10 mm away from xx :



The maximum bending stress produced in the bar at xx is nearly

- (a) 20.5 N/mm²
- (b) 18.8 N/mm²
- (c) 16.3 N/mm²
- (d) 14.5 N/mm²

Ans. (b)



Maximum bending stress $\sigma_{\max} = \frac{M}{I} \cdot Y_{\max}$

$$= \frac{1000 \times 10^3}{\left(\frac{50 \times 80^3}{12}\right)} \times 40 = 18.8 \text{ N/mm}^2$$

End of Solution

74. The frequency of oscillation is the number of cycles per unit time described by the particle, given by the relation

- (a) $f = \frac{\omega}{2\pi}$ (b) $\frac{1}{f} = \frac{\omega}{2\pi}$
 (c) $f' = \frac{2\pi r}{T}$ (d) $f' = \frac{2\pi N T}{\omega}$

Ans. (a)

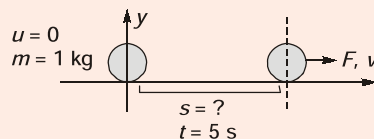
$$f = \frac{\omega}{2\pi}$$

End of Solution

75. A particle of mass 1 kg moves in a straight line under the influence of a force which increases linearly with time at the rate of 60 N/s, it being 40 N initially. The position of the particle after a lapse of 5 s, if it started from rest at the origin, will be

- (a) 1250 m (b) 1500 m
 (c) 1750 m (d) 2000 m

Ans. (c)



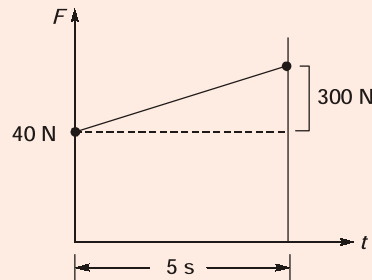
$$m = 1 \text{ kg}, \frac{dF}{dt} = 60 \text{ N/S},$$

$$\int dF = \int 60 dt$$

$$F = (60)t + C \quad \dots(i)$$

At $t = 0, F = 40, \therefore C = 40$

$$\therefore F = (60)t + 40 \quad \dots(ii)$$



\Rightarrow As $F = ma$

$$\therefore a = \frac{F}{m} = \frac{F}{1}$$

$$a = 60 t + 40 \quad \dots(iii)$$

$$\therefore \frac{dv}{dt} = 60 t + 40$$

$$\int dv = \int (60t + 40) dt$$

$$v = \frac{60t^2}{2} + 40t + c_1 \quad \dots(iv)$$

At $t = 0, v = 0, c_1 = 0$

$$\therefore v = \frac{60t^2}{2} + 40 \times t \quad \dots(v)$$

$$\frac{ds}{dt} = \frac{60t^2}{2} + 40t$$

$$\int ds = \int \left(\frac{60t^2}{2} + 40t \right) dt$$

$$s = \frac{60t^3}{6} + \frac{40t^2}{2} + c_2 \quad \dots(vi)$$

At $t = 0, s = 0, \therefore c_2 = 0$

$$\therefore s = \frac{60t^3}{6} + \frac{40t^2}{2} \quad \dots(vii)$$

At $t = 5 \text{ s}$
 $s = 1750 \text{ m}$

End of Solution

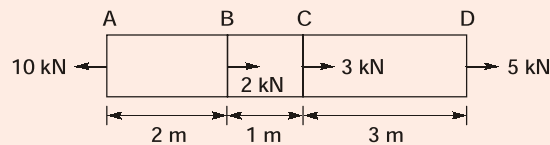
76. Rails are laid such that there will be no stress in them at 24°C. If the rails are 32 m long with an expansion allowance of 8 mm per rail, coefficient of linear expansion $\alpha = 11 \times 10^{-6}/^{\circ}\text{C}$ and $E = 205 \text{ GPa}$, the stress in the rails at 80°C will be nearly
- (a) 68 MPa (b) 75 MPa
(c) 83 MPa (d) 90 MPa

Ans. (b)

$$\begin{aligned} \text{Free exp} &= L \cdot \alpha \cdot \Delta T \\ &= 32000 \times 11 \times 10^{-6} \times 56 = 19.72 \text{ mm} \\ \text{Expansion allowance} &= 8 \text{ mm} \\ \text{Expansion resistance} &= 11.712 \text{ mm} \\ \text{Strain resistance} &= \frac{11.712}{32000} \\ \text{Stress developed} &= \frac{11.712}{32000} \times 205 \times 10^3 = 75.03 \text{ MPa} \end{aligned}$$

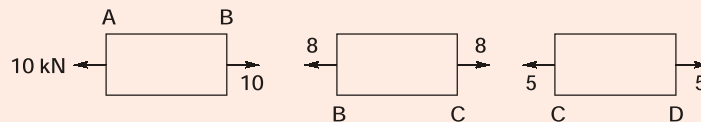
End of Solution

77. The loads acting on a 3 mm diameter bar at different points are as shown in the figure:



- If $E = 205 \text{ GPa}$, the total elongation of the bar will be nearly
- (a) 29.7 mm (b) 25.6 mm
(c) 21.5 mm (d) 17.4 mm

Ans. (a)



$$\begin{aligned} \Delta &= \Delta_{AB} + \Delta_{BC} + \Delta_{CD} \\ &= \frac{10 \times 10^3 \times 2000}{AE} + \frac{8 \times 10^3 \times 1000}{AE} + \frac{5 \times 10^3 \times 3000}{AE} \\ &= \frac{43 \times 10^6}{AE} = \frac{43 \times 10^6}{\frac{\pi}{4} \times 3^2 \times 205 \times 10^3} \\ &= 29.68 \text{ mm} \end{aligned}$$

End of Solution

78. A hollow circular bar used as a beam has its outer diameter thrice the inside diameter. It is subjected to a maximum bending moment of 60 MN m. If the permissible bending stress is limited to 120 MPa, the inside diameter of the beam will be
- (a) 49.2 mm (b) 53.4 mm
(c) 57.6 mm (d) 61.8 mm

Ans. (c)

$$d_o = 3d_i, M = 60 \text{ MN mm}$$

$$\sigma_{\max} = \frac{M}{I} \cdot y_{\max}$$

$$120 = \frac{60 \times 10^6}{\frac{\pi}{64}(d_o^4 - d_i^4)} \cdot \frac{d_o}{2} = \frac{64 \times 60 \times 10^6}{\pi d_o^3 \left[1 - \left(\frac{d_i}{d_o} \right)^4 \right]} \cdot \frac{d_o}{2}$$

$$120 = \frac{64 \times 60 \times 10^6}{2\pi d_o^3 \left[1 - \frac{1}{3^4} \right]}$$

$$d_o = 172.8 \text{ mm}$$

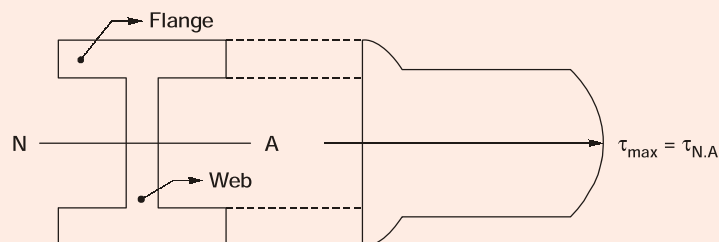
$$\therefore d_i = 57.6 \text{ mm}$$

Remark: If we take $M = 60 \text{ MN m}$, as it is given in question, then answer is not matching.

End of Solution

79. In a beam of I-section, which of the following parts will take the maximum shear stress when subjected to traverse loading?
1. Flange
 2. Web
- Select the correct answer using the code given below.
- (a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Ans. (b)



Shear stress is maximum at the neutral axis of I-section (i.e. in the web portion). Hence answer is (b).

End of Solution

80. Which of the following statements is/are correct?
1. In uniformly distributed load, the nature of shear force is linear and bending moment is parabolic.
 2. In uniformly varying load, the nature of shear force is linear and bending moment is parabolic.
 3. Under no loading condition, the nature of shear force is linear and bending moment is constant.

Select the correct answer using the code given below.

- (a) 1 and 2 (b) 1 and 3
(c) 2 only (d) 1 only

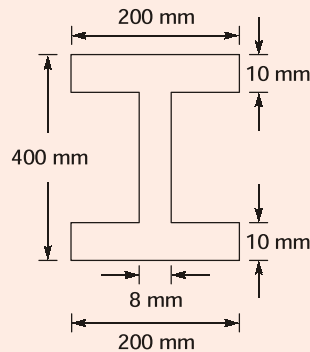
Ans. (d)

In presence of distributed loads, S.F. variation is one order higher than load intensity variation and B.M. variation is one order higher than S.F. variation or two orders higher than load intensity variation.

Hence, only 1st statement is correct.

End of Solution

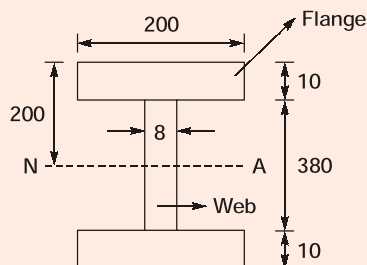
81. The cross-section of the beam is as shown in the figure:



If the permissible stress is 150 N/mm^2 , the bending moment M will be nearly

- (a) $1.21 \times 10^8 \text{ N mm}$ (b) $1.42 \times 10^8 \text{ N mm}$
(c) $1.64 \times 10^8 \text{ N mm}$ (d) $1.88 \times 10^8 \text{ N mm}$

Ans. (b)



$$I_{N.A} = 2(I_{flange})_{N.A} + I_{web}$$

$$= 2 \left[\left(\frac{1}{12} \times 200 \times 10^3 \right) + 200 \times 10 \times (200 - 5)^2 \right] + \frac{1}{12} \times 8 \times 380^3$$

$$I_{N.A} = 1.887 \times 10^8 \text{ mm}^4$$

$$Z_{N.A} = \frac{I_{N.A}}{Y_{\max}} = 943500 \text{ mm}^3$$

$$(\sigma_b)_{\max} \leq \sigma_{\text{per}}$$

$$\frac{M}{Z_{N.A}} \leq 150$$

⇒

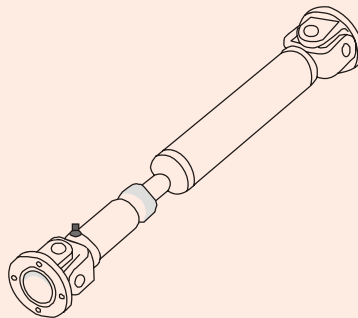
$$M = 150 \times 943500 = 141525000 \text{ N-mm}$$

$$M = 1.42 \times 10^8 \text{ N-mm}$$

End of Solution

82. In a propeller shaft, sometimes apart from bending and twisting, end thrust will also develop stresses which would be
- tensile in nature and uniform over the cross-section
 - compressive in nature and uniform over the cross-section
 - tensile in nature and non-uniform over the cross-section
 - compressive in nature and non-uniform over the cross-section

Ans. (b)



Propeller shaft is under compression due to thrust in X-Y.

End of Solution

83. A spherical shell of 1.2 m internal diameter and 6 mm thickness is filled with water under pressure until volume is increased by $400 \times 10^3 \text{ mm}^3$. If $E = 204 \text{ GPa}$, Poisson's ratio $\nu = 0.3$, neglecting radial stresses, the hoop stress developed in the shell will be nearly
- | | |
|------------|------------|
| (a) 43 MPa | (b) 38 MPa |
| (c) 33 MPa | (d) 28 MPa |

Ans. (a)

$$\text{Volumetric strain } \epsilon_v = \frac{3PD}{4tE}(1-\nu)$$

$$\frac{\Delta V}{V} = 3 \cdot \frac{\sigma_h}{E}(1-\nu)$$

$$\sigma_h = \frac{\Delta V}{V} \cdot \frac{E}{3(1-\nu)} = \frac{400 \times 10^3}{\frac{\pi}{6}(1200)^3} \times \frac{204 \times 10^3}{3(1-0.3)} = 43 \text{ MPa}$$

End of Solution

84. The inner diameter of a cylindrical tank for liquefied gas is 250 mm. The gas pressure is limited to 15 MPa. The tank is made of plain carbon steel with ultimate tensile strength of 340 N/mm², Poisson's ratio of 0.27 and the factor of safety of 5. The thickness of the cylinder wall will be

- (a) 60 mm (b) 50 mm
(c) 40 mm (d) 30 mm

Ans. (d)

$$\begin{aligned} (\sigma_{\max})_{\text{ind}} &\leq \sigma_{\text{per}} \\ \sigma_{\text{hoop}} &\leq \frac{S_{ut}}{N} \\ \frac{pD}{2t} &\leq \frac{340}{5} \\ t &\geq \frac{15 \times 250 \times 5}{2 \times 340} \\ t &= 27.57 \text{ mm} = 30 \text{ mm} \end{aligned}$$

End of Solution

85. The structure of sodium chloride is considered as
(a) a body-centered crystal
(b) a simple cubic crystal
(c) two interpenetrating FCC sub-lattices of Cl⁻ ions and Na⁺ ions
(d) a cubic crystal with Na⁺ and Cl⁻ alternatively at the cubic corners

Ans. (c)

A unit cell for NaCl crystal structure is generated from an FCC arrangement of anions, with one cation situated at the cube center and one at the center of each of the 12 cube edges. An equivalent crystal structure results from an FCC arrangement of cations. Thus, NaCl crystal structure may be thought of as two interpenetrating FCC lattices, one composed of the cations, the other of anions.

End of Solution

86. Hardenability of steel is assessed by
(a) Charpy impact test (b) Rockwell hardness test
(c) Jominy end-quench test (d) Open-hole test

Ans. (c)

The Jominy end-quench test measures hardenability of steels. Hardenability is a measure of the ability of steel to be hardened in depth, when quenched from its austenizing temperature.

End of Solution

87. A metal has lattice parameter of 2.9 \AA , density of 7.87 g/cc , atomic weight of 55.85 , and Avogadro's number is 6.0238×10^{23} . The number of atoms per unit cell will be nearly
- (a) 1 (b) 2
(c) 8 (d) 16

Ans. (b)

$$\rho = \frac{N_{av} \times \text{Atomic weight}}{6.023 \times 10^{23} \times \{\text{volume of unit cell}\}}$$

$$7.87 \text{ g/cc} = \frac{N_{av} \times 55.85}{6.023 \times 10^{23} \times \{a^3\}} = \frac{N_{av} \times 55.85}{6.023 \times 10^{23} \times \{2.9 \times 10^{-8}\}^3}$$

$$\therefore N_{av} = 2.069$$

End of Solution

88. An atomic packing factor (APF) for the BCC unit cell of hard spheres atoms will be
- (a) 0.63 (b) 0.68
(c) 0.73 (d) 0.78

Ans. (b)

$$\text{Atomic packing factor (APF)} = \frac{N_{av} \times \frac{4}{3} \pi r^3}{\text{Volume of unit cell}} = \frac{2 \times \frac{4}{3} \pi r^3}{\left(\frac{4r}{\sqrt{3}}\right)^3}$$

$$= 0.68$$

End of Solution

89. The distinct characteristic of Invar is
- (a) it is magnetic
(b) it has low coefficient of thermal expansion
(c) it has high tensile strength
(d) it is non-corrosive

Ans. (b)

To maintain dimensional stability in presence to temperature variation [i.e. zero thermal stress and strain]. 'INVAR' should be selected as the material of that component because of lower thermal coefficient of expansion [i.e. $\alpha = 1.2 \times 10^{-6}/^\circ\text{C}$].

Invar steel is an alloy of Fe and Ni containing 36% Ni. It has a very low coefficient of thermal expansion ($1.2 \times 10^{-6} \text{ K}^{-1}$) compared to ordinary steels. Hence, it is used where dimensional stability is required, such as precision instruments, clocks, creep gauges, antimagnetic parts in watches etc.

End of Solution

90. An alloy produced by adding 1% of tin to Muntz metal is called as
(a) α brass (b) Admiralty brass
(c) Naval brass (d) Leaded brass

Ans. (c)

Addition of about 1% tin to Muntz metal increases corrosion resistance to marine environments and the brass is called as Naval brass or Tobin bronze. Brass with 39% Zinc and 1% tin is used for marine hardware propeller shafts, piston rods, nuts and bolts and welding rods.

End of Solution

91. A sample of glass has a crack of half-length $2 \mu\text{m}$. The Young's modulus of glass of 70 GN/m^2 and specific surface energy is 1 J/m^2 . The fracture strength will be
(a) 885 MPa (b) 895 MPa
(c) 915 MPa (d) 935 MPa

Ans. (d)

According to Orowan theory of brittle fracture,

$$\text{Fracture stress } (\sigma_f) = \frac{1}{2} \left[\frac{E\gamma}{C} \right]^{\frac{1}{2}}$$

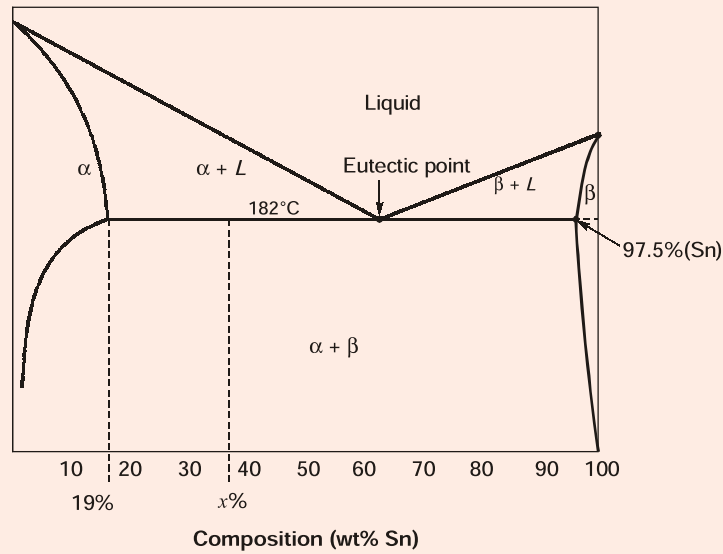
\therefore $E = \text{Young's modulus} = 70 \text{ GN/m}^2$
 $\gamma = \text{Surface Energy} = 1 \text{ J/m}^2$
 $C = \text{Crack half length} = 2 \mu\text{m}$

$$\therefore \sigma_f = \frac{1}{2} \left[\frac{70 \times 10^9 \times 1}{2 \times 10^{-6}} \right]^{\frac{1}{2}} = 935.4 \text{ MPa}$$

End of Solution

92. In the Pb-Sn system, the fraction of total α phase is 3 times the fraction of β phase at eutectic temperature of 182°C , Pb with 19% Sn dissolved in it, Sn with 2.5% Pb dissolved in it, and liquid is in equilibrium. The alloy compositions of tin (Sn) and lead (Pb) are nearly
(a) 28.6% and 71.4% (b) 38.6% and 61.4%
(c) 48.6% and 51.4% (d) 58.6% and 41.4%

Ans. (b)



$$m_{\alpha} = 3m_{\beta}$$

$$3 \times \frac{x - 19}{97.5 - 19} = \frac{97.5 - x}{97.5 - 19}$$

$$3x - 3 \times 19 = 97.5 - x$$

$$4x = 154.5$$

$$x = 38.6\%$$

End of Solution

93. A cylindrical specimen of steel having an original diameter of 12.8 mm is tensile tested to fracture and found to have engineering fracture strength σ_f of 460 MPa. If its cross-sectional diameter at fracture is 10.7 mm, the true stress at fracture will be
- (a) 660 MPa (b) 645 MPa
(c) 630 MPa (d) 615 MPa

Ans. (a)

$$\sigma_t = \sigma_0 (1 + e), \sigma_f = 460 \text{ MPa}$$

$$d_f = 10.7 \text{ mm}, d_i = 12.8 \text{ mm}$$

$$\sigma_t = \sigma_f \times \frac{A_i}{A_f} = 460 \times \left(\frac{12.8}{10.7} \right)^2$$

$$\sigma_t = 658.28 \text{ MPa}$$

End of Solution

94. An iron container 10 cm × 10 cm at its base is filled to a height of 20 cm with a corrosive liquid. A current is produced as a result of an electrolytic cell, and after four weeks, the container has decreased in weight by 70 g. If $n = 2$, $F = 96500$ C and $M = 55.84$ g/mole, the current will be
- (a) 0.05 A (b) 0.10 A
(c) 0.20 A (d) 0.40 A

Ans. (b)

$$\begin{aligned} \text{Material removed} &= 70 \text{ g} \\ \text{Time} &= 4 \text{ weeks} \\ &= 4 \times 7 \times 24 \times 3600 = 2419200 \text{ sec} \\ \text{MRR (g/s)} &= \frac{70}{2419200} = 0.000028935 \\ \text{MRR} &= \frac{eI}{F} \\ I &= \frac{\text{MRR} \times F}{e} \\ &= \frac{0.000028935 \times 96500}{\left(\frac{55.85}{2}\right)} = 0.10 \text{ A} \end{aligned}$$

End of Solution

95. A copper piece originally 305 mm long is pulled in tension with a stress of 276 MPa. If the deformation is entirely elastic and the modulus of elasticity is 110 GPa, the resultant elongation will be nearly
- (a) 0.43 mm (b) 0.54 mm
(c) 0.65 mm (d) 0.77 mm

Ans. (d)

$$\delta L = \frac{PL}{AE} \text{ or } \frac{\sigma_a L}{E} = \frac{276 \times 305}{110 \times 10^3} = 0.765 \text{ mm} \simeq 0.77 \text{ mm}$$

End of Solution

96. The indentation on a steel sample has been taken using 10 mm tungsten carbide ball at 500 kgf load. If the average diameter of the indentation is 2.5 mm, the BHN will be nearly
- (a) 90 (b) 100
(c) 110 (d) 120

Ans. (b)

$$\text{BHN} = \frac{2P}{\pi D \left\{ D - \sqrt{D^2 - d^2} \right\}}$$

$$= \frac{2 \times 500}{\pi \times 10 \left\{ 10 - \sqrt{10^2 - 2.5^2} \right\}} = 100.242$$

∴

D = diameter of indenter (mm)

d = diameter of indentation (mm)

P = applied load (kgf)

End of Solution

97. Which of the following statements are correct with respect to inversion of mechanisms?
1. It is a method of obtaining different mechanisms by fixing different links of the same kinematic chain.
 2. It is a method of obtaining different mechanisms by fixing the same links of different kinematic chains.
 3. In the process of inversion, the relative motions of the links of the mechanisms produced remain unchanged.
 4. In the process of inversion, the relative motions of the links of the mechanisms produced will change according.

Select the correct answer using the code given below.

(a) 1 and 3

(b) 1 and 4

(c) 2 and 3

(d) 2 and 4

Ans. (a)

According to the question they will be successive links and hence the relative motion will remain same. Motion characteristics individually may change but relative motions of the links of th mechanisms produced remain unchanged.

End of Solution

98. For the follower with stroke S , following the cycloidal motion, the radius of the rolling circle will be

(a) $S \times 2\pi$

(b) $\frac{S}{2\pi}$

(c) $\frac{2\pi}{S}$

(d) $S + 2\pi$

Ans. (b)

$$2\pi R = S$$

$$R = \frac{S}{2\pi}$$

End of Solution

99. A vertical shaft of 100 mm diameter and 1 m length has its upper end fixed at the top. The other end carries a disc of 5000 N and the modulus of elasticity of the shaft material is 2×10^5 N/mm². Neglecting the weight of the shaft, the frequency of the longitudinal vibrations will be nearly
- (a) 279.5 Hz (b) 266.5 Hz
(c) 253.5 Hz (d) 241.5 Hz

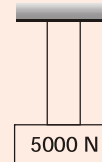
Ans. (a)

$$d = 100 \text{ mm} = 0.1 \text{ m}$$

$$l = 1 \text{ m}$$

$$mg = 5000 \text{ N}$$

$$E = 2 \times 10^5 \text{ N/mm}^2 = 2 \times 10^{11} \text{ N/m}^2$$



Longitudinal stiffness

$$s = \frac{AE}{l} = \frac{\frac{\pi}{4}(0.1)^2 \times 2 \times 10^{11}}{1}$$

$$s = 1570796327 \text{ N/m}$$

$$\omega_n = \sqrt{\frac{s}{m}} = \sqrt{\frac{1570796327}{\left(\frac{5000}{9.81}\right)}} = 1755.5347 \text{ rad/s}$$

$$f_n = \frac{\omega_n}{2\pi} = 279.4020 \text{ Hz}$$

End of Solution

100. The accurate method of finding the natural frequency of transverse vibrations of a system of several loads attached to some shaft is
- (a) Dunkerley method (b) Energy method
(c) Stodola method (d) Dunkerley and energy method

Ans. (d)

End of Solution

101. The speed at which the shaft runs, so that the deflection of the shaft from the axis of rotation becomes infinite, is known as
- (a) whipping speed (b) damping speed
(c) resonant speed (d) gravitational speed

Ans. (a)

End of Solution

102. Which one of the following is not the correct statement with respect to the involute profile toothed gears in mesh?
- (a) Pressure angle remains constant from the start till the end of the engagement.
 - (b) The base circle diameter and the pitch circle diameter of the two mating involutes are proportional.
 - (c) When two involutes are in mesh, the angular velocity ratio is proportional to the size of the base circles.
 - (d) The shape of the involute profile depends only on the dimensions of the base circle.

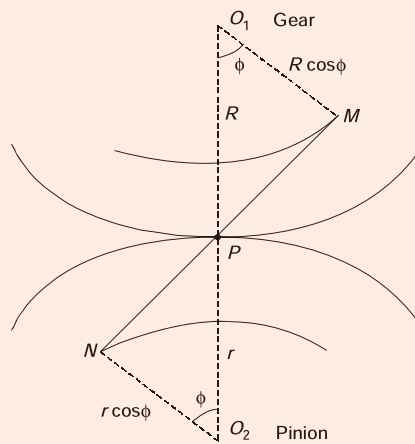
Ans. (b)

End of Solution

103. The centre distance C between two gears, in terms of base circle radii R_1 , R_2 and the pressure angle ϕ , is

- (a) $\frac{\cos \phi}{R_1 + R_2}$
- (b) $\frac{R_1 + R_2}{\cos \phi}$
- (c) $\left(\frac{R_1}{R_2}\right) \cdot \cos \phi$
- (d) $\left(\frac{R_2}{R_1}\right) \cdot \cos \phi$

Ans. (b)



$$R_1 = R \cos \phi$$

$$\Rightarrow R = \frac{R_1}{\cos \phi}$$

$$R_2 = r \cos \phi$$

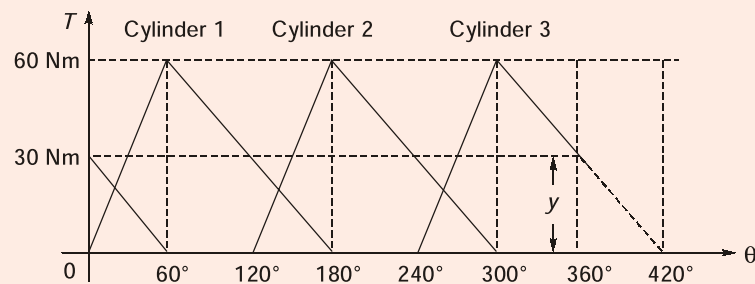
$$\Rightarrow r = \frac{R_2}{\cos \phi}$$

$$\text{Centre distance} = (R + r) = \frac{R_1}{\cos \phi} + \frac{R_2}{\cos \phi} = \frac{(R_1 + R_2)}{\cos \phi}$$

End of Solution

104. A three-cylinder single-acting engine has its cranks at 120° . The turning moment diagram for each cycle is a triangle for the power stroke with a maximum torque of 60 Nm at 60° after the dead centre of the corresponding crank. There is no torque on the return stroke. The engine runs at 400 rpm. The power developed will be
- (a) 1745 W (b) 1885 W
(c) 1935 W (d) 1995 W

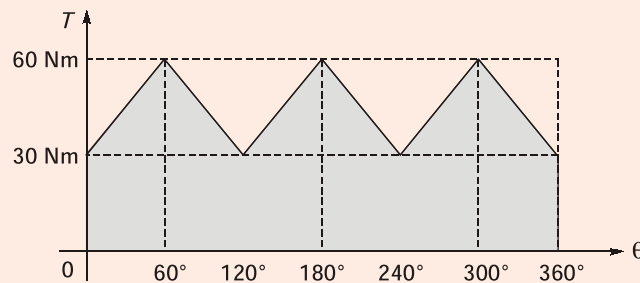
Ans. (b)



$$\frac{60}{120} = \frac{y}{60}$$

$$y = \frac{60}{2} = 30 \text{ Nm}$$

Total turning moment diagram,



$W_{\text{cycle}} = \text{Area under the } (T - \theta) \text{ diagram}$

$$= \left[\frac{(30 \times 2\pi/3)}{2} + \left(30 \times \frac{2\pi}{3} \right) \right] \times 3$$

$$= [10\pi + 20\pi] \times 3 = 90\pi$$

$$T_{\text{mean}} = \frac{90\pi}{2\pi} = 45 \text{ Nm}$$

Power developed

$$P = T_{\text{mean}} \times \omega$$

$$= 45 \times \frac{2\pi \times 400}{60}$$

$$= 1884.96 = 1885 \text{ Watt}$$

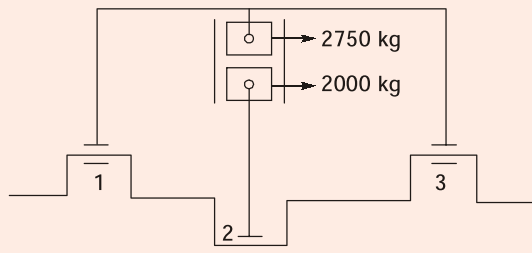
(N = 400 rpm)

End of Solution

105. A vertical single-cylinder opposed piston type engine has reciprocating parts of mass 2000 kg for the lower piston and 2750 kg for the upper piston. The lower piston has a stroke of 60 cm and the engine is in primary balance. If the ratio of the length of connecting rod to crank is 4 for the lower piston and 8 for the upper piston, and when the crankshaft speed is of 135 rpm, the maximum secondary unbalanced force will be
- (a) 48935.5 N (b) 46946.5 N
(c) 44968.5 N (d) 42989.5 N

Ans. (c)

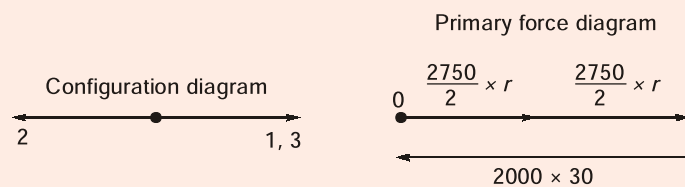
Vertical single cylinder opposed piston type engine:



lower piston crank radius = $\frac{60}{2} = 30$ cm

Upper piston crank radius = r (Assume)

Planes	m (kg)	r (m)	$m.r$
1	$\frac{2750}{2}$	r	$\frac{2750}{2} \times r$
2	2000	30	(2000×30)
3	$\frac{2750}{2}$	r	$\left(\frac{2750}{2} \times r\right)$



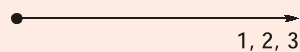
For primary balance:

$$\left[\frac{2750}{2} \times r \right] \times 2 = 2000 \times 30$$

\Rightarrow

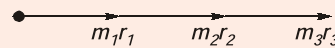
$$r = 21.8181 \text{ cm}$$

Secondary configuration diagram



Planes	m (kg)	$r/4n$	$m.r/4n$
1	$\frac{2750}{2} = 1375$	$\frac{21.8181}{(4 \times 8)} = 0.68181$	937.496
2	2000	$\frac{30}{4 \times 4} = 1.875$	3750
3	$\frac{2750}{2} = 1375$	$\frac{21.8181}{(4 \times 8)} = 0.68181$	937.496

Secondary force polygon



$$= 937.496 + 3750 + 937.496 = 5624.992 \text{ kg-cm}$$

$$= 56.24992 \text{ kg-m}$$

$$F_{\text{secondary}} = m \frac{r}{4n} \times (2\omega)^2 = 56.24992 \times \left(2 \times 2\pi \times \frac{135}{60} \right)^2$$

$$= 44968.3211 \text{ N}$$

End of Solution

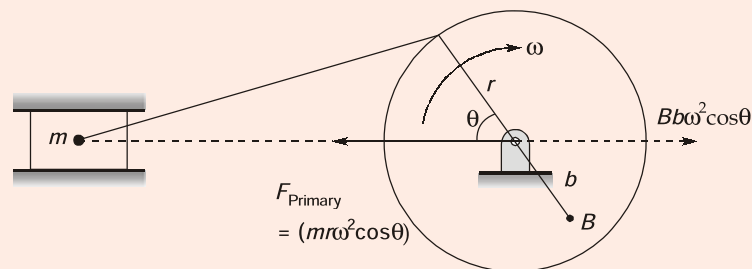
106. The reciprocating mass is balanced when primary force is

1. balanced by the mass = $cmr\omega^2\cos\theta$
2. unbalanced by the mass = $cmr\omega^2\cos\theta$
3. balanced by the mass = $(1 - c)cmr\omega^2\cos\theta$
4. unbalanced by the mass = $(1 - c)cmr\omega^2\cos\theta$

Select the correct answer using the code given below.

- | | |
|-------------|-------------|
| (a) 1 and 3 | (b) 2 and 3 |
| (c) 1 and 4 | (d) 2 and 4 |

Ans. (c)



$$B \cdot b = cmr$$

$$\text{Balance mass} = B \cdot b = cmr$$

$$\text{Balance mass force along line of stroke} = B \cdot b \omega^2 \cos\theta = cmr\omega^2 \cos\theta$$

$$\text{Force unbalanced along line of stroke, } F_{UN} = mr\omega^2 \cos\theta - B \cdot b \omega^2 \cos\theta$$

$$= mr\omega^2 \cos\theta - cmr\omega^2 \cos\theta$$

$$= (1 - c)mr\omega^2 \cos\theta$$

End of Solution

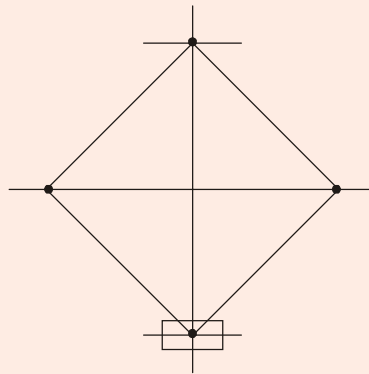
107. The active gyroscopic torque in gyroscope about a horizontal axis represents
- (a) the torque required to cause the axis of spin to precess in the vertical plane
 - (b) the torque required to cause the axis of spin to precess in the horizontal plane
 - (c) the force required to cause the axis of spin to precess in the horizontal plane
 - (d) the force required to cause the axis of spin to precess in the vertical plane

Ans. (b)

End of Solution

108. The change in governor height for a Watt governor when speed varies from 100 rpm to 101 rpm will be nearly
- (a) 1.8 mm
 - (b) 2.6 mm
 - (c) 3.4 mm
 - (d) 4.2 mm

Ans. (a)



Watt governor equilibrium equation, $h = \frac{895}{N^2}$

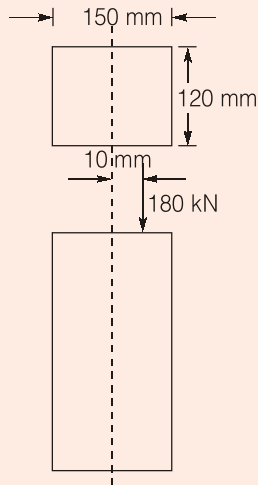
$$h_1 = \frac{895}{(100)^2} = 0.0895$$

$$h_2 = \frac{985}{(101)^2} = 0.087736$$

$$\begin{aligned} \text{Change, } \Delta h &= h_1 - h_2 \\ &= 1.7635 \times 10^{-3} \text{ m} = 1.7635 \text{ mm} \\ &\simeq 1.8 \text{ mm} \end{aligned}$$

End of Solution

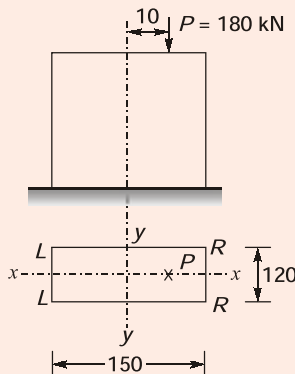
109. A rectangular strut is 150 mm wide and 120 mm thick. It carries a load of 180 kN at an eccentricity of 10 mm in a plane bisecting the thickness as shown in the figure:



The maximum intensity of stress in the section will be

- (a) 14 MPa (b) 12 MPa
(c) 10 MPa (d) 8 MPa

Ans. (a)



Resultant normal stress is maximum at the right side fiber (R.F.) of the cross section, because the line of action of eccentric axial compressive load is nearer to this fiber.

$$\sigma_{\max} = \sigma_{R.F} = \sigma_a + (\sigma_b)_{\max}$$

$$\sigma_{\max} = (-) \left[\frac{P}{A} + \frac{M}{Z_{yy}} \right]$$

$$\sigma_{\max} = (\text{comp.}) \left[\frac{180 \times 10^3}{150 \times 120} + \frac{180 \times 10^3 \times 10}{\frac{1}{6} \times 120 \times 150^2} \right]$$

$$\sigma_{\max} = 14 \text{ MPa (comp.)}$$

End of Solution

110. The theory of failure used in designing the ductile materials in a most accurate way is by

1. maximum principal stress theory
2. distortion energy theory
3. maximum strain theory

Select the correct answer using the code given below

- | | |
|----------------|------------|
| (a) 1, 2 and 3 | (b) 1 only |
| (c) 2 only | (d) 3 only |

Ans. (c)

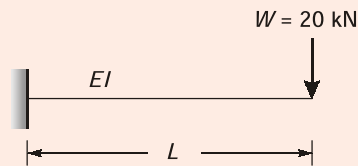
Maximum distortion energy theory is the best theory of failure for safe and economic design of ductile material components.

End of Solution

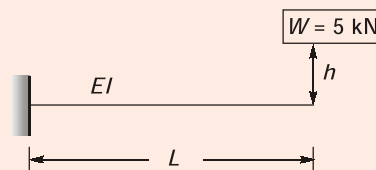
111. When a load of 20 kN is gradually applied at a particular point in a beam, it produces a maximum bending stress of 20 MPa and a deflection of 10 mm. What will be the height from which a load of 5 kN should fall into the beam at the same point if the maximum bending stress is 40 MPa?

- | | |
|-----------|-----------|
| (a) 80 mm | (b) 70 mm |
| (c) 60 mm | (d) 50 mm |

Ans. (c)



$$\begin{aligned} (\sigma_{\text{static}})_{\text{max}} &= 20 \text{ MPa} \\ \delta_{\text{static}} &= 10 \text{ mm} \end{aligned}$$



$$\begin{aligned} \sigma_{\text{static}} &= 5 \text{ MPa} \quad (\text{load becomes } 1/4\text{th}) \\ \delta_{\text{static}} &= 2.5 \text{ mm} \end{aligned}$$

$$\sigma_{\text{impact}} = \sigma_{\text{st}} \times \text{impact factor}$$

$$40 = 5 \left[1 + \sqrt{1 + \frac{2h}{\delta_{\text{static}}}} \right] = 5 \left[1 + \sqrt{1 + \frac{2h}{2.5}} \right]$$

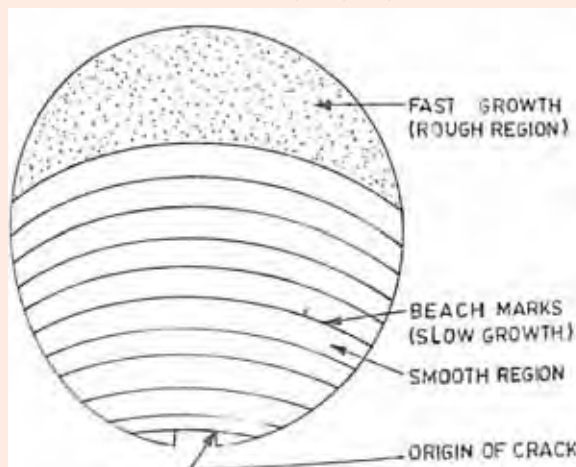
$$h = 60 \text{ mm}$$

End of Solution

112. The areas of fatigue failure in a part may be in the
- region having slow growth of crack with a fine fibrous appearance.
 - region having faster growth of crack with a fine fibrous appearance.
 - region of sudden fracture with a coarse granular appearance.
 - region of gradual fracture with a coarse granular appearance.
- Select the correct answer using, the code given below.
- (a) 2 and 3 (b) 2 and 4
(c) 1 and 4 (d) 1 and 3

Ans. (d)

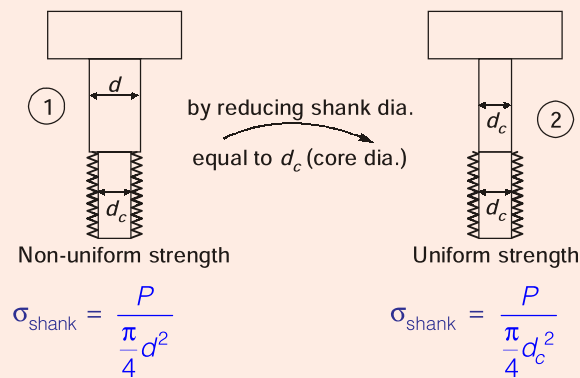
The process of fatigue failure is characterized by (i) crack initiation, (ii) crack propagation and (iii) final failure, which occurs very rapidly.



End of Solution

113. The shock-absorbing capacity (resilience) of bolts can be increased by
- increasing the shank diameter above the core diameter of threads
 - reducing the shank diameter to the core diameter of threads
 - decreasing the length of shank portion of the bolt
 - pre-heating of the shank portion of the bolt

Ans. (b)



$$(SE)_1 = \frac{\sigma^2}{2E}(V)$$

$$\left(\frac{SE}{V}\right)_1 = \frac{\sigma^2}{2E}$$

$$\left(\frac{SE}{V}\right)_2 = \frac{\sigma^2}{2E}$$

In bolt '2' $\sigma_{\text{shank-2}} > \sigma_{\text{shank-1}}$

Hence, $\left(\frac{SE}{V}\right)_2 > \left(\frac{SE}{V}\right)_1$

Hence bolt '2' can bear more shock than '1'

End of Solution

114. The torque required to tighten the bolt comprises of the
- torque required in overcoming thread friction only
 - torque required in inducing the pre-load only
 - torque required in overcoming circumferential hoop stress
 - torque required in overcoming thread friction and inducing the pre-load and also the torque required to overcome collar friction between the nut and the washer

Ans. (d)
For tightening

$$\text{Torque} = F_{\text{pre}} \frac{d_m}{2} (\tan(\alpha + \phi))$$

Hence torque required to overcome pre-load and thread friction.

End of Solution

115. A steel spindle transmits 4 kW at 800 rpm. The angular deflection should not exceed 0.25°/m length of the spindle. If the modulus of rigidity for the material of the spindle is 84 GPa, the diameter of the spindle will be
- 46 mm
 - 42 mm
 - 38 mm
 - 34 mm

Ans. (d)

$$\text{Power} = \frac{2\pi NT}{60}$$

$$T = 47.7 \text{ Nm}$$

Now, $\frac{\theta}{L} = \frac{T}{GJ}$

$$0.25 \times \frac{\pi}{180} = \frac{47.7 \times 10^3}{84 \times 10^3 \times J} \times 10^3$$

$$J = 130209.28 \text{ mm}^4$$

$$\frac{\pi}{32} d^4 = 130209.28$$

$$\therefore d = 33.95 \text{ mm}$$

End of Solution

116. A taper roller bearing has a dynamic load capacity of 26 kN. The desired life for 90% of the bearings is 8000 hr and the speed is 300 rpm. The equivalent radial load that the bearing can carry will be nearly
- (a) 5854 N (b) 5645 N
(c) 5436 N (d) 5227 N

Ans. (a)

$$L_{90} = 8000 \times 60 \times 300 = 144 \text{ MR}$$

$$144 = \left(\frac{C}{P_{eq}} \right)^{10/3} = \left(\frac{26000}{P_{eq}} \right)^{10/3}$$

$$\Rightarrow P_{eq} = 5854 \text{ N}$$

End of Solution

117. Hollow shafts are stronger than solid shafts having same weight because
- (a) the stiffness of hollow shaft is less than that of solid shaft
(b) the strength of hollow shaft is more than that of solid shaft
(c) the natural frequency of hollow shaft is less than that of solid shaft
(d) in hollow shafts, material is not spread at large radius

Ans. (b)

For same weight, polar section modulus (Z_p) of hollow circular cross-section is more than Z_p of solid circular cross section. Hence, torque transmission capacity of hollow circular cross section is more.

End of Solution

118. A propeller shaft is required to transmit 45 kW power at 500 rpm. It is a hollow shaft having inside diameter 0.6 times the outside diameter. It is made of plain carbon steel and the permissible shear stress is 84 N/mm². The inner and outer diameters of the shaft are nearly.
- (a) 21.7 mm and 39.1 mm (b) 23.7 mm and 39.1 mm
(c) 21.7 mm and 32.2 mm (d) 23.5 mm and 32.2 mm

Ans. (b)

$$P = \frac{2\pi NT}{60}$$

$$T = 0.8598 \text{ kNm}$$

$$\text{For hollow shaft, } \tau_{\max} = \frac{16T}{\pi d_o^3 \left[1 - \left(\frac{d_i}{d_o} \right)^4 \right]}$$

$$84 = \frac{16 \times 0.8598 \times 10^6}{\pi d_o^3 [1 - 0.6^4]}$$

$$d_o = 39.13 \text{ mm}$$

$$\therefore d_i = 23.47 \text{ mm}$$

End of Solution

119. A bicycle and rider travelling at 12 km/hr on a level road have a mass of 105 kg. A brake is applied to a rear wheel having 800 mm diameter. The pressure on the brake is 80 N and the coefficient of friction is 0.06. The number of turns of the wheel before coming to rest will be
- (a) 48.3 revolutions (b) 42.6 revolutions
(c) 38.3 revolutions (d) 32.6 revolutions

Ans. (a)

$$\text{number of revolution} = \frac{s}{\pi D}$$

$$\text{Friction force} = \mu R_H = 4.8 \text{ N}$$

$$ma = F_r$$

$$a = \frac{4.8}{105}$$

$$v_f^2 = v_1^2 + 2as$$

$$0 = \left(\frac{10}{3}\right)^2 + 2 \times \frac{4.8}{105} \times s$$

$$s = 121.52 \text{ m}$$

$$\text{number of revolution} = \frac{121.52}{\pi \times 8} = 48.3 \text{ revolutions}$$

End of Solution

120. To avoid self-engagement in cone clutch, its semi-cone angle is always kept
- (a) smaller than the angle of static friction
(b) equal to the angle of static friction
(c) greater than the angle of static friction
(d) half of the angle of static friction

Ans. (c)

To avoid self locking semi-cone angle should be greater than angle of static friction.

End of Solution

121. In case of arc welding of steel with a potential of 20V and current of 200A, the travel speed is 5 mm/s and the cross-sectional area of the joint is 20 mm². The heat required for melting steel may be taken as 10 J/mm³ and heat transfer efficiency as 0.85. The melting efficiency will be nearly
- (a) 18% (b) 29%
(c) 36% (d) 42%

Ans. (b)

$$\text{Potential} = 20 \text{ V}$$

$$\text{Current} = 200 \text{ A}$$

$$\text{Travel speed} = 5 \text{ mm/s}$$

$$\text{Cross-sectional area} = 20 \text{ mm}^2$$

Heat required for welding = 10 J/mm^3

Heat transfer efficiency = 0.85

$$\text{Power} = VI = 20 \times 200 = 4000 \text{ J/s}$$

$$P_{\text{eff}}, \text{ effective power} = 4000 \times 0.85 = 3400 \text{ J/s}$$

Heat required for melting steel = 10 J/mm^3

Vol. of molten metal per unit time that can be obtained

$$= \frac{3400 \text{ J/s}}{10 \text{ J/mm}^3} = 340 \text{ mm}^3/\text{s}$$

Required vol. of weld per unit time = Area of cross-section \times travel speed

$$= 20 \times 5 = 100 \text{ mm}^3/\text{s}$$

$$\text{Melting efficiency} = \frac{\text{Required vol. of weld per unit time}}{\text{Vol. of molten metal per unit time that can be obtained}}$$

$$= \frac{100}{340} = 0.29$$

End of Solution

122. What is the force required for 90° bending of St50 steel of 2 mm thickness in a V-die, if the die opening is taken as 8 times the thickness and the length of the bent part is 1 m, ultimate tensile strength is 500 MPa and $K = 1.33$?

(a) 166.25 kN

(b) 155.45 kN

(c) 154.65 kN

(d) 143.85 kN

Ans. (a)

$$F = \frac{kL\sigma_{ut}t^2}{w}$$

die opening factor, $k = 1.33$

width of die-opening, $w = 8t = 16 \text{ mm}$

blank thickness, $t = 2 \text{ mm}$

ultimate tensile strength, $\sigma_{ut} = 500 \text{ MPa}$

Bend length, $L = 1000 \text{ mm}$

$$F = \frac{1.33 \times 1000 \times 500 \times 2^2}{16} \text{ N}$$

$$= 166,250 \text{ N} = 166.25 \text{ kN}$$

End of Solution

123. A graph is drawn to a vertical magnification of 10000 and horizontal magnification of 100 and the areas above and below the datum line are as follows:

Above	150mm ²	80mm ²	170mm ²	40mm ²
Below	80mm ²	60mm ²	150mm ²	120mm ²

The average roughness R_a for sampling length of 0.8 mm will be

- (a) 1.14 μm (b) 1.10 μm
(c) 1.06 μm (d) 1.02 μm

Ans. (c)

$$R_a = \frac{\Sigma a + \Sigma b}{L \times V \times H}$$

$$= \frac{(150 + 80 + 170 + 40 + 80 + 60 + 150 + 120)}{0.8 \times 10000 \times 100} \times 1000$$

$$= 1.06 \mu\text{m}$$

End of Solution

124. The radius of arc is measured by allowing a 20 mm diameter roller to oscillate to and fro on it and the time for 25 oscillations is noted at 56.25 s. The radius of arc will be

- (a) 865 mm (b) 850 mm
(c) 835 mm (d) 820 mm

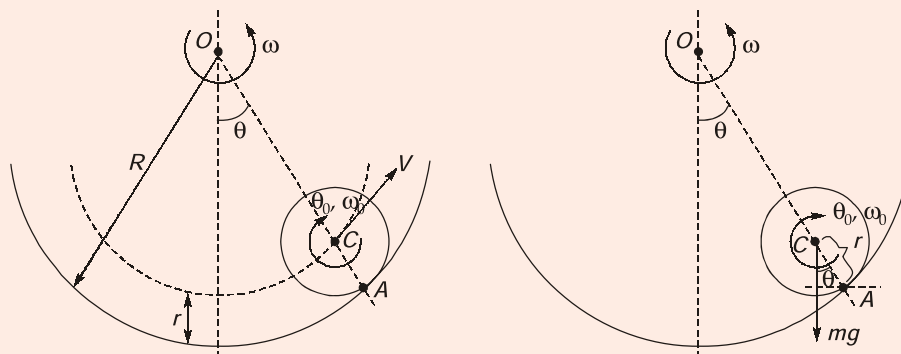
Ans. (b)

$$d = 20 \text{ mm (Roller diameter)}$$

$$r = 10 \text{ mm} = 0.01 \text{ m (Roller-radius)}$$

$$T = \frac{56.25}{25} = 2.25 \text{ s}$$

Arc radius $R = ?$



Let at any instant roller has velocity 'v' as shown.
for very small time, $\theta_0 \rightarrow$ angle turned by roller w.r.t. 'A'

$\omega_0 \rightarrow$ angular velocity of roller w.r.t. 'A'

$v = r\omega_0 \rightarrow$ w.r.t. 'A'

and for same time, $\theta \rightarrow$ angle turned by roller w.r.t. 'O'

$\omega \rightarrow$ angular velocity of roller w.r.t. 'O'

$v = (R - r)\omega \rightarrow$ w.r.t. 'O'

or
$$r \times \frac{d\theta_0}{dt} = (R - r) \frac{d\theta}{dt} \quad \dots(i)$$

also,
$$r \times \frac{d^2\theta_0}{dt^2} = (R - r) \times \frac{d^2\theta}{dt^2} \quad \dots(ii)$$

About point 'A' restoring torque = $mgr \sin\theta = mgr\theta$ (if θ is very small)

$$I_A = \frac{mr^2}{2} + mr^2 = \frac{3}{2}mr^2$$

Hence, apply $I_A \times \frac{d^2\theta_0}{dt^2} = - mgr\theta$

$$\frac{3}{2}mr^2 \frac{d^2\theta_0}{dt^2} + mgr\theta = 0$$

$$\frac{3}{2}r^2 \frac{d^2\theta_0}{dt^2} + gr\theta = 0$$

As, $(R - r)\theta = r\theta_0$

$$\theta = \left(\frac{r\theta_0}{R - r} \right)$$

or $\theta_0 = \frac{\theta}{r}(R - r)$

$$\frac{3}{2} \times r^2 \times \frac{d^2}{dt^2} \left[\frac{\theta}{r}(R - r) \right] + gr\theta = 0$$

$$\frac{d^2\theta}{dt^2} + \frac{2g}{3(R - r)}\theta = 0$$

So, $\omega_n = \sqrt{\frac{2g}{3(R - r)}}$

$$T = 2\pi \sqrt{\frac{3(R - r)}{2g}}$$

$\therefore 2.25 = 2\pi \sqrt{\frac{3(R - 0.01)}{2 \times 9.81}}$

$$R = 0.8482 \text{ m}$$

$$R = 848.2 \text{ mm} \simeq 850 \text{ mm}$$

End of Solution

125. Which one of the following systems is consisting of processing stations, material handling and storage, computer control system and human labour?
 (a) Portable manufacturing system (b) Focused integrated system
 (c) Flexible manufacturing system (d) Automated integrated system

Ans. (c)

End of Solution

126. A project initially costs ₹ 5000 and generates year-end cash inflows of ₹1,800, ₹1,600, ₹1,400, ₹1,200 and ₹1,000 respectively in five years of its life. If the rate of return is 10%, the net present value (NPV) will be
 (a) ₹ 500 (b) ₹ 450
 (c) ₹ 400 (d) ₹ 350

Ans. (b)

$$\begin{aligned} \text{NPV} &= -5000 + 1800 \times \frac{1}{(1.1)^1} + 1600 \times \frac{1}{(1.1)^2} + 1400 \times \frac{1}{(1.1)^3} + 1200 \times \frac{1}{(1.1)^4} + 1000 \times \frac{1}{(1.1)^5} \\ &= 451.04 \simeq ₹450 \end{aligned}$$

End of Solution

127. What is the mode for the following distribution?

Gross profit as percentage of sales	Number of companies
0–7	19
7–14	25
14–21	36
21–28	72
28–35	51
35–42	43
42–49	28

- (a) 19.55 (b) 21.40
 (c) 23.25 (d) 25.10

Ans. (d)

End of Solution

128. Consider the following data for quality acceptance process:
 $N = 10000$, $n = 89$, $c = 2$, $p = 0.01$ (incoming lots of quality), $P_a = 0.9397$
 The AOQ will be
 (a) 0.93% (b) 0.84%
 (c) 0.75% (d) 0.66%

Ans. (a)

$$AOQ = p \cdot p_a$$

$$p = 0.01$$

and

$$p_a = p_0 + p_1 + p_2$$

$$p_0 = {}^{89}C_0 (0.01)^0 (0.99)^{89} = 0.4088$$

$$p_1 = {}^{89}C_1 (0.01)^1 (0.99)^{88} = 0.36752$$

$$p_2 = {}^{89}C_2 (0.01)^2 (0.99)^{87} = 0.16334$$

$$p_a = 0.4088 + 0.36752 + 0.16334 = 0.93966$$

$$AOQ = 0.01 \times 0.93966 \times 100 \\ = 0.93966\% \approx 0.93\%$$

End of Solution

129. An engine is to be designed to have a minimum reliability of 0.8 and minimum availability of 0.98 over a period of 2×10^3 hr. The MTTR is nearly
- (a) 168 hr (b) 174 hr
(c) 183 hr (d) 188 hr

Ans. (c)

$$R = e^{-\lambda t}$$

$$0.8 = e^{-\lambda \times 2000}$$

$$\lambda = 0.0001115$$

$$MTBF = \frac{1}{\lambda} = \frac{1}{0.0001115} = 8968.60 \text{ hr}$$

$$A = \frac{MTBF}{MTBF + MTTR}$$

$$0.98 = \frac{8968.60}{8968.60 + MTTR}$$

$$MTTR = 183 \text{ hr}$$

End of Solution

130. Which one of the following relation with usual notations will hold good in a dynamic vibration absorber system under tuned conditions?
- (a) $k_1 k_2 = m_1 m_2$ (b) $k_1 m_2 = m_1 k_2$
(c) $k_1 m_1 = k_2 m_2$ (d) $k_1 + k_2 = m_1 + m_2$

Ans. (b)

End of Solution

131. In ultrasonic waves, the frequencies for non-destructive testing of materials are in the range of
- (a) 0.5 MHz to 10 MHz (b) 10 MHz to 20 MHz
(c) 20 MHz to 30 MHz (d) 30 MHz to 40 MHz

Ans. (a)

As per the American society for non-destructive testing (ASNT).
The most common sound frequencies used in ultrasonic testing are between 1.0 – 10 MHz.
Since option (a) i.e. 0.5 MHz – 10 MHz is within the range specified by ASNT.

End of Solution

132. The Curie point for most ferrous magnetic materials is about
- (a) 390°C (b) 540°C
(c) 760°C (d) 880°C

Ans. (c)

For ferromagnetic materials, the saturation magnetization decreases with increase in temperature, and touches a value of zero, at about 760°C, This is called curie point.

End of Solution

133. Which of the following is one of the basic units of memory controller in micro-controller?
- (a) Microcode engine (b) Master program counter
(c) Program status word (d) Slave program counter

Ans. (d)

End of Solution

134. Which one of the following ways will be adopted to store the program counter contents?
- (a) Last-in-First-out (LIFO) (b) First-in-First-out (FIFO)
(c) Last-in-Last-out (LILO) (d) First-in-Last-out (FILO)

Ans. (a)

End of Solution

135. In ladder logic programming, an alternative in place of using same internal relay contact for every rung is to use
- (a) battery-backed relay (b) dummy relay
(c) one-shot operation (d) master control relay

Ans. (d)

End of Solution

136. Consider the following statements :

1. The term 'attenuation' is used to describe the process of removing a certain band of frequencies from a signal and permitting others to be transmitted.
2. The Wheatstone bridge can be used to convert a voltage change to an electrical resistance change.

Which of the above statements is/are correct?

- (a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Ans. (d)

Attenuation: It is the process of reducing the strength of signal of particular frequencies but not of removing signal of some frequencies. So statements 1 is wrong.

Wheatstone bridge: Wheatstone bridge is used to convert the change in resistance into voltage. Because in basic resistive bridge, the output voltage of the bridge is given by

$$V_{OB} = \frac{V_s \cdot \Delta R}{4 R_0}$$

$$V_{OB} \propto \Delta R$$

' V_{OB} ' is bridge output voltage.

' V_s ' is the source voltage applied to bridge.

' ΔR ' is change in resistance.

R_0 is initial resistance of sensor.

As output voltage of bridge is directly proportional to change in resistance, statement 2 is also wrong.

End of Solution

137. At time t , the excitation voltage to a resolver is 24 V. The shaft angle is 90° . The output signals from the resolver V_{s1} and V_{s2} will be

- (a) 12 V and 0 V (b) 24 V and 0 V
(c) 12 V and 12 V (d) 24 V and 12 V

Ans. (b)

Resolver generates two secondary voltage for any particular position of the shaft.

$$V_{s2}(t) = (kV_i \cos\theta) \sin\omega t$$

$$V_{s1}(t) = (kV_i \sin\theta) \sin\omega t$$

The amplitude of $V_{s1}(t)$ and $V_{s2}(t)$ at particular time ' t ' are given as

$$V_{s1} = kV_i \sin\theta$$

$$V_{s2} = kV_i \cos\theta$$

Given that;

$$V_i = 24$$

Let's consider

$$k = 1$$

Then

$$V_{s1} = 1 \times 24 \sin(90) = 24 \text{ V}$$

$$V_{s2} = 1 \times 24 \cos(90) = 0 \text{ V}$$

End of Solution

138. An actuator having a stem movement at full travel of 30 mm is mounted with a control valve having an equal percentage plug and with minimum flow rate of 2 m³/s and maximum flow rate of 24 m³/s. When the stem movement is 10 mm, the flow rate will be
- (a) 3.4 m³/s (b) 3.8 m³/s
(c) 4.2 m³/s (d) 4.6 m³/s

Ans. (d)

The relation between flow rate and stem movement of equal percentage plug is given as

$$Q = Q_0 e^{\beta x} \quad \dots(1)$$

'Q₀' is minimum flow rate when stem movement x is zero.

'x' is stem movement.

'β' is constant.

'Q' is flow rate for given stem movement.

Given that

$$Q_0 = 2 \text{ m}^3/\text{s}, \text{ when } x = 0 \text{ mm}$$

$$Q_{\text{max}} = 24 \text{ m}^3/\text{s}, \text{ when } x = 30 \text{ mm}$$

So, consider equation (1)

at

$$x = 30 \text{ mm}$$

$$24 = 2e^{\beta(30 \times 10^{-3})}$$

$$\beta = \frac{\ln\left(\frac{24}{2}\right)}{30 \times 10^{-3}} = 0.08283 \times 10^3$$

at

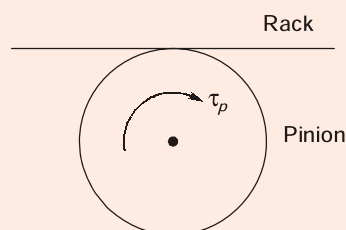
$$x = 2 \times e^{0.08283 \times 10^3 \times 10^{-3}}$$

$$Q = 4.59$$

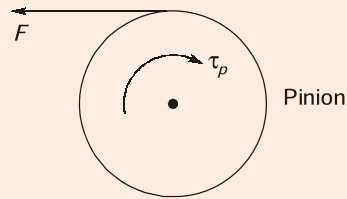
End of Solution

139. In a rack and pinion system, rack is an element moving in translational direction and pinion is a rotary gear. Which one of the following statements is correct?
- (a) Translational acceleration is directly proportional to the moment of inertia of pinion.
(b) Translational acceleration is inversely proportional to the moment of inertia of pinion.
(c) Angular acceleration is inversely proportional to the torque on pinion shaft.
(d) Translational velocity is directly proportional to the moment of inertia of pinion.

Ans. (b)

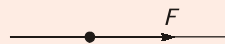


FBD of pinion



$$\tau_p - F \times r_p = I_p \alpha_p \quad \dots(i)$$

FBD of Rack



$$F = m_R a_R \quad \dots(ii)$$

By (i) and (ii)

$$\tau_p - m_R a_R r_p = I_p \alpha_p$$

$$a_R = \left(\frac{\tau_p - I_p \alpha_p}{m_R r_p} \right)$$

⇒ When I_p increases a_R decreases, therefore inversely proportional.

End of Solution

140. For the control signal to change at a rate proportional to the error signal, the robotic controller must employ
- integral control
 - proportional-plus-integral control
 - proportional-plus-derivative control
 - proportional-plus-integral-plus-derivative control

Ans. (a)

Given that the control signal to change at a rate proportional to the error signal it means

$$\frac{d}{dt} (\Delta I(t)) \propto E(t)$$

$$\Delta I(t) = K_I \int E(t) dt$$

$\Delta I(t)$ = change of control signal (controller output)

$E(t)$ = Error signal

As the change of control signal is proportional to the integral of error, it represents "Integral controller".

End of Solution

141. What is the minimum number of degrees of freedom that a robot needs to have in order to locate its end effectors at an arbitrary point with an arbitrary orientation in space?
(a) 3 (b) 4
(c) 5 (d) 6

Ans. (a)

Only 3 DOF required to locate end effectors in arbitrary space.

Do not confuse with 6 DOF.

Actually robot requires 6 DOF to perform arbitrary tasks that includes both arm and wrist movements. In the given question, only location of end effector is asked so we need 3-DOF of robot arm.

Global positioning of industrial robot is by arm only with

1. Rotational reverse
2. Vertical traverse
3. Radial traverse

End of Solution

142. Using a robot with 1 degree of freedom and having 1 sliding joint with a full range of 1 m, if the robot's control memory has a 12-bit storage capacity, the control resolution for the axis of motion will be
(a) 0.236 mm (b) 0.244 mm
(c) 0.252 mm (d) 0.260 mm

Ans. (b)

Control memory = 12 bit

Number of increments = $2^{12} = 4096$

Total range of sliding joint = 1 m = 1000 mm

$$\text{Control resolution} = \frac{1000}{4096} = 0.244 \text{ mm}$$

End of Solution

143. Assume that the joint mechanisms at serial link manipulators are frictionless. The joint torque τ required to bear an arbitrary end point force F is
(a) $J^{-1}F$ (b) JF
(c) $J^T F$ (d) $J^{-1}F^T$

Ans. (c)

Static force analysis is about finding relationship between end effector force 'F' and joint torque (T).

Moreover, static force analysis uses matrix(J) which can be derived by velocity analysis. Relation between F and T.

F = end effector force

T = joint torque

$$T = [J]^T \{F\}$$

This question is out of syllabus.

End of Solution

144. Rotate the vector $v = 5i + 3j + 8k$ by an angle of 90° about the x-axis. The rotated vector (Hv) would be

(a) $\begin{bmatrix} 1 \\ 3 \\ -8 \\ 5 \end{bmatrix}$

(b) $\begin{bmatrix} -8 \\ 5 \\ 1 \\ 3 \end{bmatrix}$

(c) $\begin{bmatrix} 3 \\ -8 \\ 5 \\ 1 \end{bmatrix}$

(d) $\begin{bmatrix} 5 \\ -8 \\ 3 \\ 1 \end{bmatrix}$

Ans. (d)

Frame:

$$\text{Rot}(x, \theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}, v = 5i + 3j + 8k$$

$$\text{Rot}(x, 90^\circ) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 90 & -\sin 90 \\ 0 & \sin 90 & \cos 90 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

$$R \text{ of } v|_{x, 90^\circ} = \begin{bmatrix} \begin{matrix} {}^1R_2 & | & {}^1D_2 \\ \hline 0 & 0 & 0 \end{matrix} & & \\ \hline & & 1 \end{bmatrix} \begin{bmatrix} 5 \\ 3 \\ 8 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 5 \\ 3 \\ 8 \\ 1 \end{bmatrix} = \begin{bmatrix} 5 \\ -8 \\ 3 \\ 1 \end{bmatrix}$$

End of Solution

Directions : Each of the six (6) items consists of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. You are to examine these two statements carefully and select the answers to these items using the code given below :

Codes:

- (a) Both Statement (I) and Statement (II) are individually true; and Statement (II) is the correct explanation of Statement (I)
- (b) Both Statement (I) and Statement (II) are individually true; but Statement (II) is NOT the correct explanation of Statement (I)
- (c) Statement (I) is true; but Statement (II) is false
- (d) Statement (I) is false; but Statement (II) is true

Q.145 Statement (I) : The function of arithmetic logic unit (ALU) in microprocessor is to perform data manipulation.

Statement (II) : The status register is where data for an input to the arithmetic and logic unit is temporarily stored.

Ans. (c)

End of Solution

Q.146 Statement (I) : To use a sensor, we generally need to add signal conditioning circuitry, such as circuits which amplify and convert from analog to digital, to get the sensor signal in the right form, take account of any non-linearities, and calibrate it.

Statement (II) : A smart sensor is integrated with the required buffering and conditioning circuitry in a single element and provides functions beyond that of just a sensor.

Ans. (b)

- General sensor like 'strain gauge' provides low electrical resistance change (ΔR), corresponding to applied force (F). But to transmit this low value of digital meter, we require amplifier and analog to digital converter etc.
 - The extra equipment (circuitry/devices) required to convert the output of sensor into more appropriate form is called as 'signal conditioning circuit'.
 - Normal sensors requires extra 'signal conditioning' elements. But where as 'SMART SENSORS' has inbuilt 'Signal conditioning' circuitry.
- Because both the statements are individually correct but statement '2' is not the explanation of statement '1'.

End of Solution

Q.147 Statement (I) : The count-up overflow (OV) bit is 1 when the up-counter increments above the maximum positive value.

Statement (II) : The count-down underflow (UN) bit is 1 when the counter decrements below the minimum negative value.

Ans. (c)

End of Solution

Q.148 Statement (I) : The multiplexer is essentially an electronic switching device which enables each of the inputs to be sampled in turn.

Statement (II) : A multiplexer is a circuit that is able to have inputs of data from a number of sources and then, by selecting an input channel, gives an output from just one of them.

Ans. (a)

End of Solution

Q.149 Statement (I) : The term 'encoder' is used for a device that provides an analog output as a result of angular or linear displacement.

Statement (II) : An increment encoder detects changes in angular or linear displacement from some datum position where as an absolute encoder gives the actual angular or linear position.

Ans. (d)

- 'Encoder' means a device which generates digital output [CODE]. So statement I is wrong.
- 'Incremental encoder' generates pulse for every constant change in input position (linear/angular).
Whereas absolute encoder generates digital code, corresponding to input position both linear/angular position. So statement II is correct.

End of Solution

Q.150 Statement (I) : Process control valves are used to control the rate of fluid flow and are used where, perhaps, the rate of flow of a liquid into a tank has to be controlled.

Statement (II) : A common form of pneumatic actuator used with process control valves is the diaphragm actuator.

Ans. (b)

- Process control valves are used to regulate the flow (both direction of flow, and magnitude of flow rate) in process industry. So statement I is correct.
- Diaphragm actuator is basic control valve, which provides stem movement corresponding to input pressure and stem movement is used to regulate the flow rate. So statement II is correct.
Both the statements are individually correct but statement II is not the explanation of statement I.

End of Solution